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Semiannual Report 4 | *Covering the Period 1 September 1964 through 31 March 1965*

RESEARCH-ENGINEERING AND SUPPORT FOR TROPICAL COMMUNICATIONS

Compiled by: R. E. LEO G. H. HAGN W. R. VINCENT

Prepared for:

U.S. ARMY ELECTRONICS COMMAND
FORT MONMOUTH, NEW JERSEY

CONTRACT DA-36-039-AMC-00040(E)
ORDER NO. 5384-PM-63-9

STANFORD RESEARCH INSTITUTE

MENLO PARK, CALIFORNIA

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ORDER NO. 5384-PM-63-91
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Compiled by: R. E. LEO G. H. HAGN W. R. VINCENT

SRI Project 4240

Approved: D. R. SCHEUCH, EXECUTIVE DIRECTOR
ELECTRONICS AND RADIO SCIENCES

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PREFACE

The work described in this report was performed with the support, and using the facilities, of the Military Research and Development Center at Bangkok, Thailand, a joint United States-Thailand organization. The cooperation of staff members of the Thailand Ministry of Defense, the United States Advanced Research Projects Agency, and the United States Army Electronics Command made possible the work described.

In several cases, work described has been conducted under the supervision of, or by, Thai personnel assigned to the Military Research and Development Center. Examples of such work are the ground constant effort, accomplished by Major Termpoon Kovattana, and the effort on dipole orientation, where work conducted in Thailand was under the direction of Lt. Cmdr. Paibul Nacaskul.

This report summarizes the technical effort conducted under Contract DA-36-039-AMC-00040(E) for the period covering 1 September 1964 through 31 March 1965. Readers interested in additional technical detail of work accomplished are urged to consult the published reports listed in Section III. These reports present detailed discussions of specific scientific investigations.

The operations analysis work conducted under the contract will be reported separately in accordance with a special report schedule.

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I INTRODUCTION

A. HISTORICAL BACKGROUND

During World War II, United States military forces operated extensively in tropical areas, thereby gaining considerable practical experience in communication problems in tropical forest and jungle areas. The pressure of military objectives limited scientific explorations into many of the specific problems that arose, resulting in sizable gaps in our knowledge of communication in equatorial regions.

The friendly and cooperative working arrangement existing between Thailand and the U.S. resulted in the joint study of tropical communication problems by staff members of the Thailand Ministry of Defense and agencies of the U.S. The Military Research and Development Center (MRDC), was organized as a joint Thailand-U.S. agency to conduct operational tests of military hardware and to foster research on many subjects in a tropical environment. Communications research is a major subject of interest in MRDC.

The United States Army Electronics Command (USAECOM) and Stanford Research Institute (SRI) undertook the task of establishing an Electronics Laboratory in Thailand to facilitate a first-hand study of tropical communication problems. Staffing of the laboratory is a joint U.S.-Thailand venture, with U.S. participation largely from members of the staff of SRI. Figure 1 shows the Bangkok Laboratory Area.

Over-all direction of the U.S. portion of MRDC has been assigned to the Advanced Research Projects Agency (ARPA) of the Department of Defense. ARPA actively monitors and directs the work of (USAECOM) and SRI.

This function in Bangkok is carried out by the ARPA Research and Development Field Unit (RDFU).

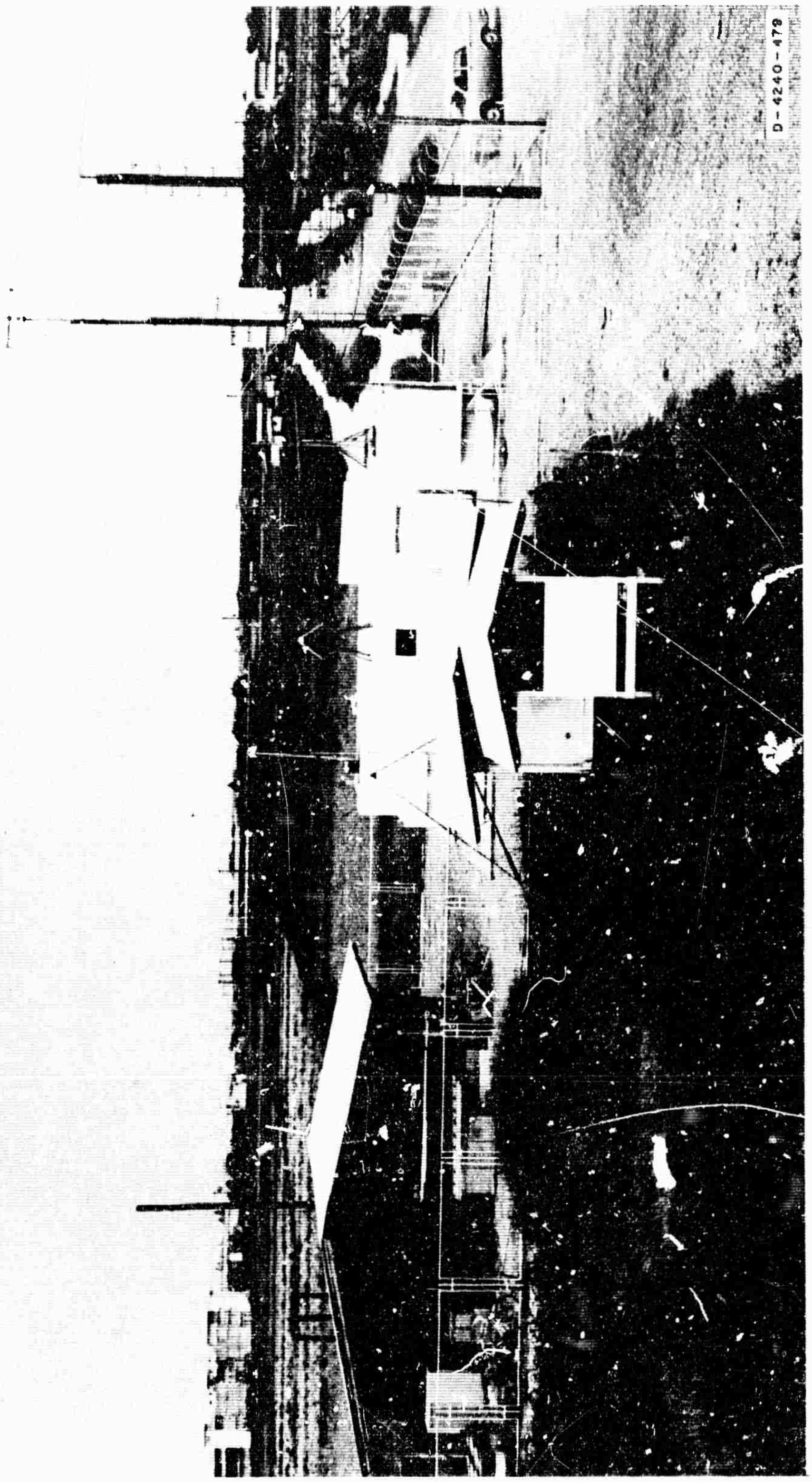

FIG. 1 BANGKOK LABORATORY AREA

B. OBJECTIVES

The purpose of the Task II portion of the project under Contract DA-36-039-AMC-00040(E) is to perform scientific and technical investigations and to support MRDC in the areas of tactical and tropical communications. The specific objectives of this effort are to:

(1) Establish environmental suitability of certain communication techniques and establish values of environmental factors.

(2) Solve existing communication problems, and provide necessary engineering data to solve future communication problems.

(3) Conduct technical tests of appropriate off-the-shelf equipments.

(4) Analyze and evaluate the tests and recommend areas for future emphasis.

(5) State the equipment requirements to accomplish the task of jungle field communication based upon existing and anticipated tactical requirements.

(6) Train the Thai personnel assigned to the Electronics Laboratory so that they can utilize the facility, accomplishing this training as a natural course of operating the laboratory.

(7) Aid electronics projects in Thailand that appear especially useful to MDRC basic objectives, and which enhance the scientific development of Thailand.

II SCIENTIFIC AND TECHNICAL INVESTIGATIONS

A. PROGRAM OBJECTIVES AND SCOPE

The project effort is concerned with Southeast Asian equatorial and tropical radio communications. Military communications within Thailand are either medium-distance, point-to-point communications or short-distance contact between a base station and a mobile patrol. Either base or patrol station may be located in many types of terrain or vegetation.

VHF may be used for short distance paths, and where the signal attenuation due to dense intervening forest is not too great. HF skywave communication is utilized for path lengths beyond VHF capabilities, or for short paths in heavy forest or mountainous areas.

Several unique communications problems exist because of the usage of HF for short paths; the use of HF in heavily forested areas; the high radio noise levels in Thailand due to high tropical thunderstorm activity; the effect of heavy forest on VHF; the influence of being near the magnetic equator in ionospherically-propagated waves; and the special military problems of the kind of warfare conducted in Southeast Asia.

To study such problems, several related research areas are being investigated. These major work efforts are defined by the following set of subtasks, and are augmented by more general efforts in support of the MRDC laboratory.

Subtask 1--Test and Evaluate Tactical Communications Techniques and Devices
Subtask 2--Conduct RF Noise Measurements
Subtask 3--Conduct Antenna Orientation Investigations
Subtask 4--Measurements of Ground Constants
Subtask 5--Special Magnetic and Ionospheric Investigations
Subtask 6--Investigate Ionospheric Factors Related to Local Frequency Prediction

Subtask 7--Investigate Effects of Tropical Environment on Antenna Performance

Subtask 8--Analysis of Vertical-Incidence Ionospheric Measurements.

B. WORK ACCOMPLISHED DURING REPORTING PERIOD

During the reporting period, work was accomplished on all the above subtasks. A summary of the work accomplished on each subtask follows.

1. Subtask 1--Test and Evaluate Tactical Communications Techniques and Devices

During the reporting period, the first Jansky & Bailey (J & B) path loss data from Thailand became available.[1]* The data are for vertical polarization, frequency range of 880 kc-400 Mc, distances of 0.2 to 17 miles, and receiving antenna heights of about 7 to 80 feet. These data were presented in the J & B Report as Figs. 3.4.18 and 3.4.19, and are reproduced here as Fig. 2. The transmitting antenna was at 80 feet, and the receiving antenna was at about 7 feet (height of antenna on vehicle). These data were taken on radials with different path profiles. The forest area is near Korat, Thailand and is described in previous J & B Semiannual Reports.

It was desirable to relate this data to the performance of man-pack radios in use, and proposed for use, in Thailand. A Special Technical Report entitled, "Use of Ground Wave Path Loss Data to Predict the Effective Range and Performance of VHF Man-Pack Radios in Forest," by George H. Hagn, is in preparation. The AN/PRC-10 was used for example calculations. The preliminary conclusions reached by Hagn in the draft report are summarized below.

A definition of the median effective range $(R_{ME})^{\dagger}$ of VHF man-pack radios for a given communication situation in terms of path loss data and a measure of system performance (error rate or intelligibility

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* References appear at the end of the report.

† This can be considered, on the average, to be the maximum range.

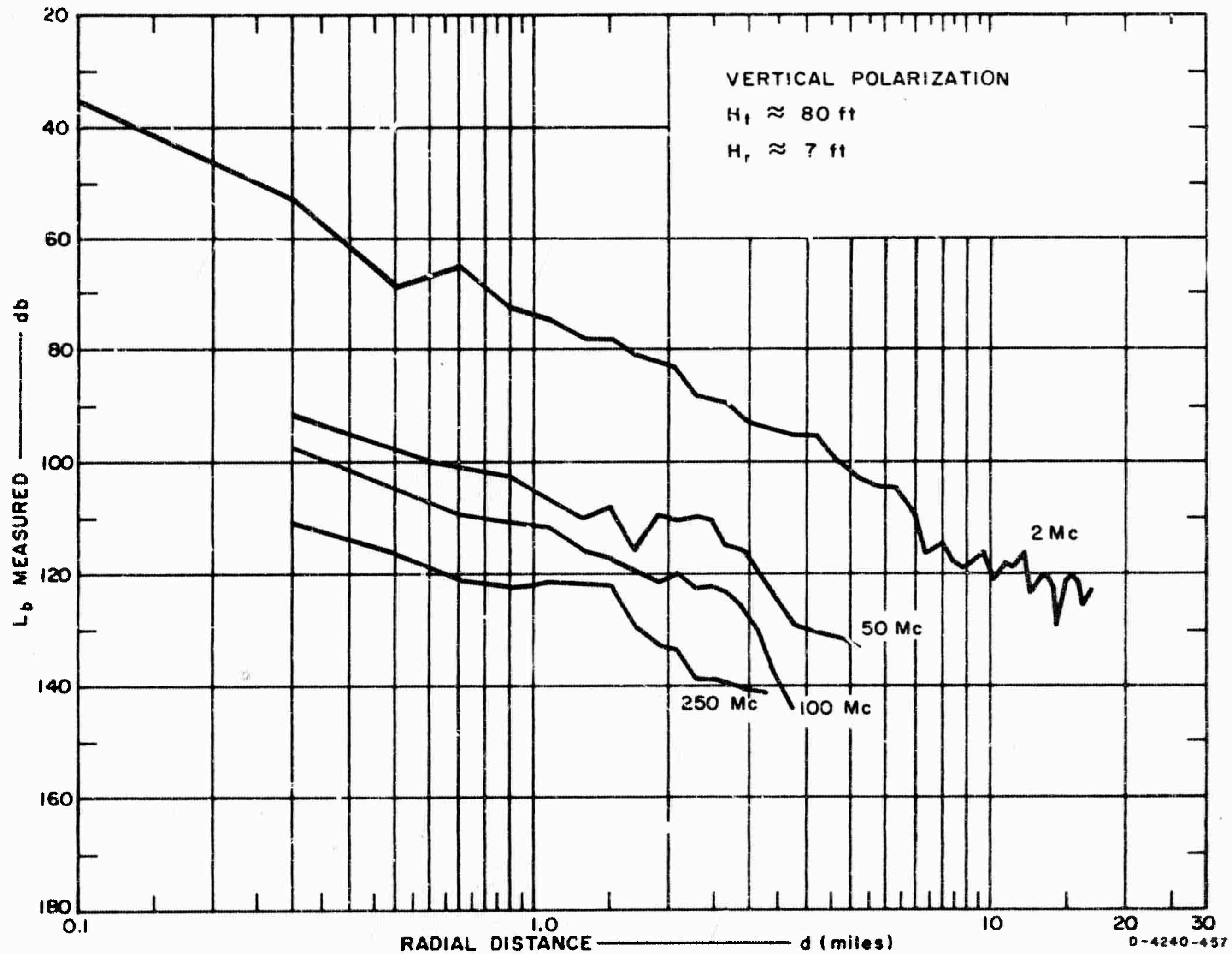

FIG. 2 J & B FOREST PATH-LOSS DATA

score, etc.) is given as the range at which the probability of successful communication is 0.5 (by some a priori agreed-upon criterion). Statistical bounds are placed upon R_{ME}, and an example calculation for the AN/PRC-10 is given for the situation of communication using a set at back-pack level and a set elevated to 80 feet in a tropical forest environment and operating on 50 Mc. For the case of 10-foot whip antennas (long whip issued with the set) employing vertical polarization, the maximum permissible basic transmission loss ($L_{bmax} \approx 115$ db) $R_{ME} \approx$ 2-1/2 miles, and an estimate of the probable error (50 percent confidence bound) indicates minimum and maximum anticipated effective range bounds of 1 and 4-1/2 miles, respectively.

One can observe from Fig. 2 that if one has a system operating at its maximum range, the increase in system sensitivity (increase in maximum permissible path loss) required to provide a given increase in range is itself a function of range. Such an increase in maximum permissible path loss could be achieved by using an auxiliary amplifier (such as with the AN/PRC-25), or possibly a higher gain antenna. Figure 3 shows the probable increase in system sensitivity in decibels (increase in maximum permissible path loss) needed to increase the maximum range of point-to-point communications by a desired amount in the forest where the J & B measurements were made near Pak Chong, Thailand at 50 Mc and for the parameters shown. For the case examined ($R_{ME} \approx 2.5$ miles), the increase required to double R_{ME} for the AN/PRC-10 in the tropical forest, 50 Mc, and vertical polarization was approximately 15 db.

Such an increase in range can also be obtained by decreasing the path loss, which can be accomplished by elevating the back-pack set antennas. This is possibly a more expedient solution in the field when auxiliary amplifiers and antennas are not available. Figure 4 shows the bounds on the measured receiving antenna height-gain curves for the example case.

The values in the shaded area depict the measured receiving height gain in vegetation from ranges from 0.2 to 10 miles and this relationship is seen (within the bounds shown) to be independent of range over this interval. Calculated height gain functions for a flat earth

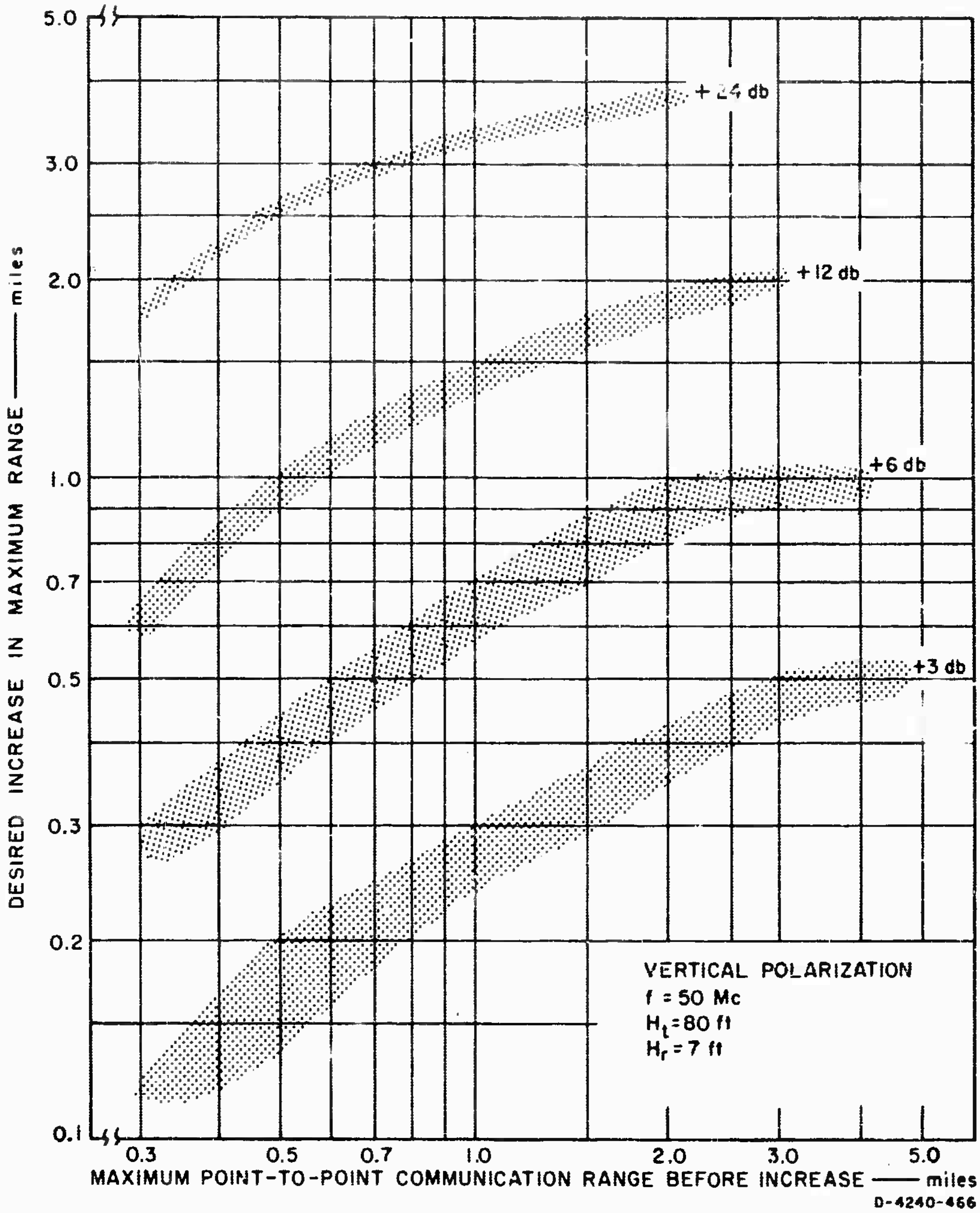

FIG. 3 PROBABLE INCREASE IN SYSTEM SENSITIVITY IN db NEEDED TO INCREASE MAXIMUM RANGE OF 50 Mc, VERTICALLY POLARIZED POINT-TO-POINT COMMUNICATION BY A DESIRED AMOUNT IN THE FOREST NEAR PAK CHONG, THAILAND

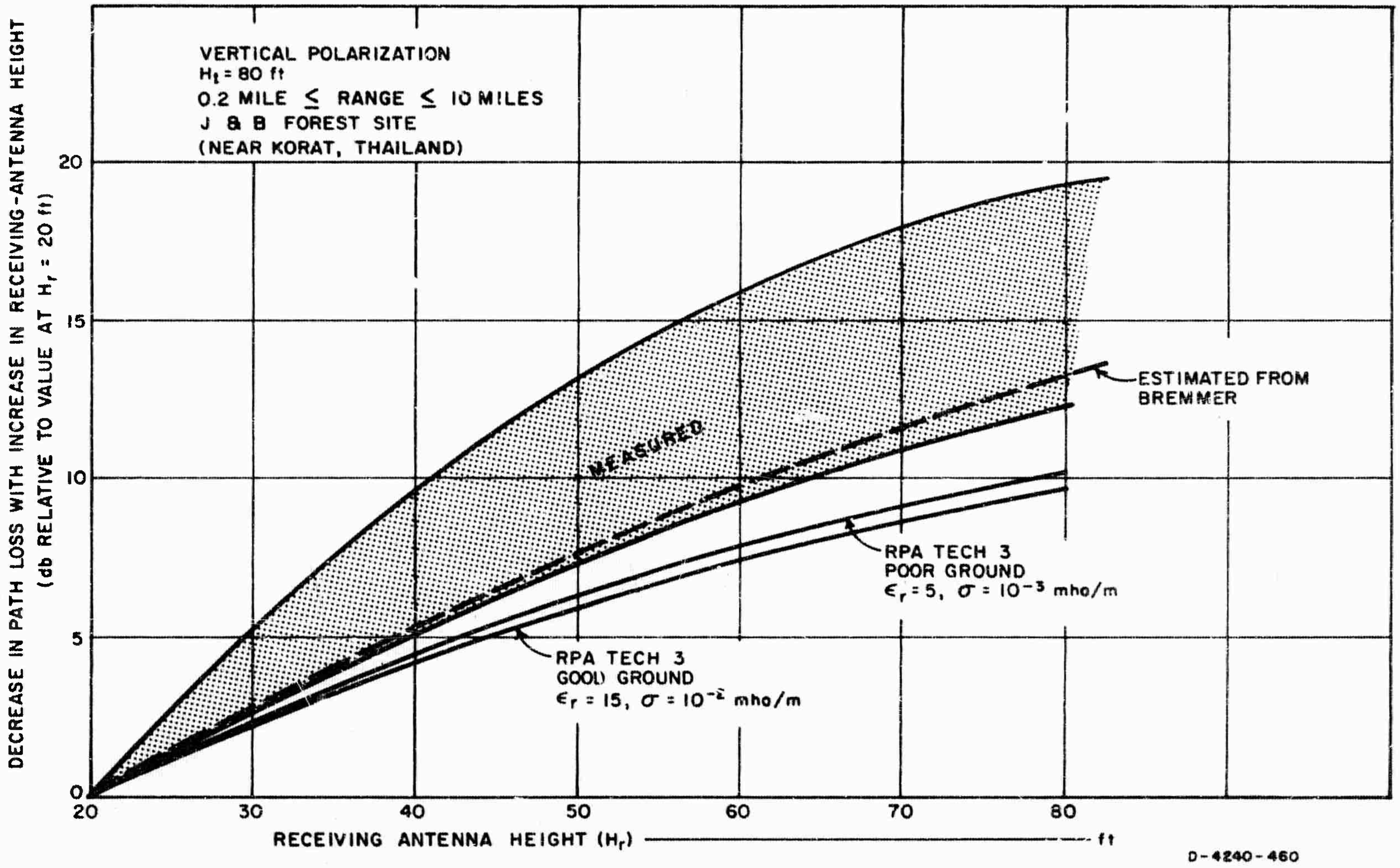

FIG. 4 RECEIVING HEIGHT GAIN CURVES, 50 Mc

and no vegetation, as obtained from the U.S. Army Radio Propagation Agency RPA Technical Report 3[2] and an estimate of the same function based on a calculation presented by Bremmer,[3] are shown for comparison.

The results shown in Figs. 3 and 4 are replotted in Fig. 5 to depict the increase in maximum range (over the maximum range for H_r = 2 ft) for various antenna heights. In the above example, R_{ME} for the AN/PRC-10 could be doubled by elevating the back-pack antenna to approximately 50 feet.

It should be noted that these conclusions about median effective range are preliminary and apply only to 50 Mc with vertical polarization in the forest for which the data were available. The values, when corrected for antenna height effects, agree reasonably well with those estimated by Hagn in November 1964 and Shrauger and Taylor in February 1965 for the AN/PRC-10 used at back-pack heights in the forest area north of Rayong, Thailand.

2. Subtask 2--RF Noise Measurements

During this report period, a number of efforts have been applied to the study of radio noise. These may be summarized as: a low-noise field site survey; a literature search on the application of ARN-2 type of data to radio systems; design of the ARN-3 type of noise measurement equipment; antenna (coaxial feed with and without balun) noise measurements; a study of band occupancy; operation of a noise direction finder; study of the correlation of thunderstorm activity and radio noise maps; study of local noise with a lightning flash counter; and study of various noise properties and characteristics by means of a six-channel VLF noise recorder. Examples of some of these efforts follow.

a. Selection of MRDC Low-Noise Field Site

Noise-measuring equipment (ARN-3 type) has been designed for use in Thailand in accordance with an NBS* prototype model. The present MRDC Electronics Laboratory field site in Bangkok has high man-made noise levels and, therefore, is not suitable for atmospheric noise measurements. After formulation of electrical and logistical requirements,

* National Bureau of Standards

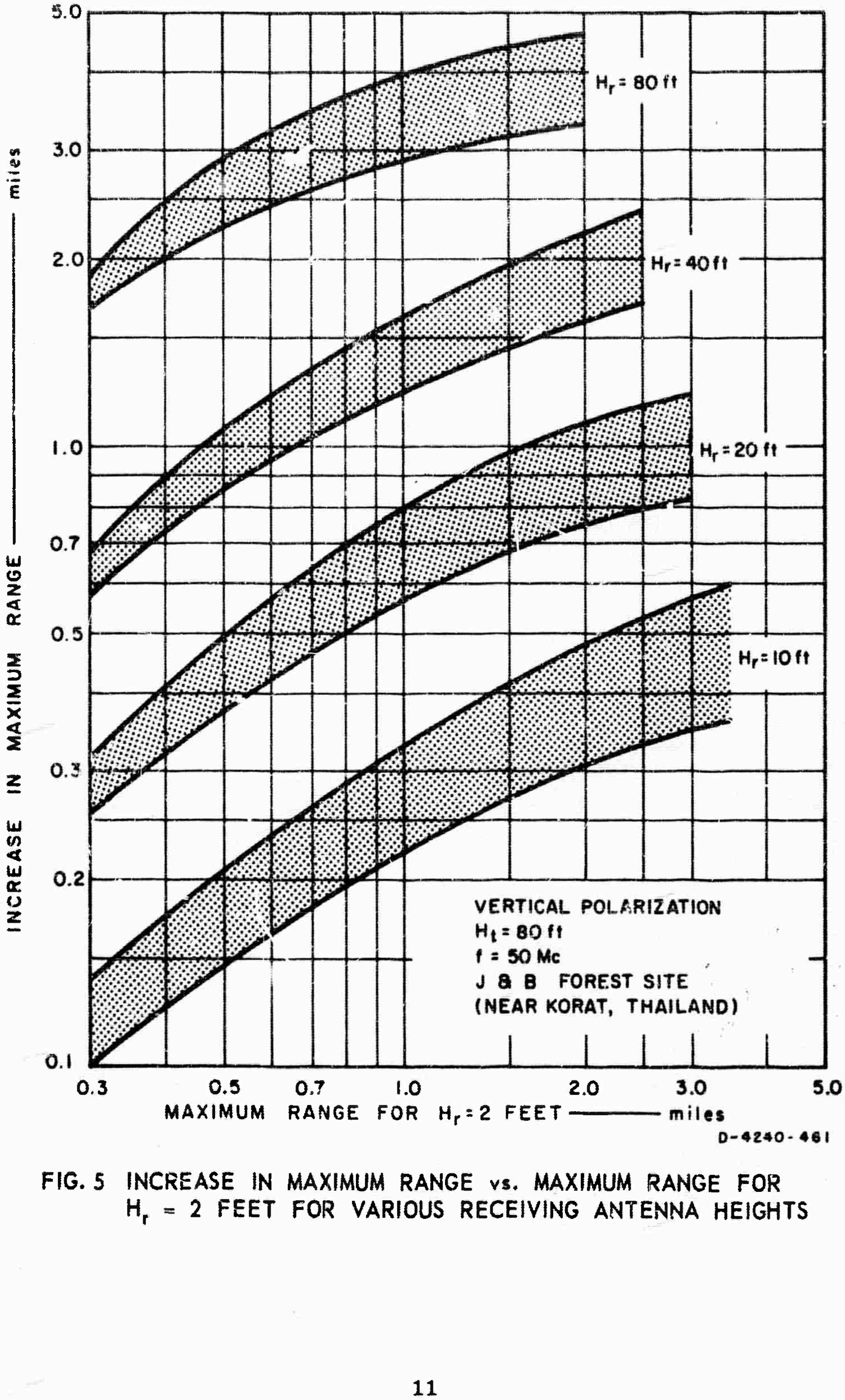

FIG. 5 INCREASE IN MAXIMUM RANGE vs. MAXIMUM RANGE FOR H_r = 2 FEET FOR VARIOUS RECEIVING ANTENNA HEIGHTS

a brief measurement program produced recommendations for an appropriate site for such measurements.

The principal unit to be installed at the low-noise site is a four-channel ARN-3-type noise measuring device.

Other equipment will be riometers for measuring cosmic noise and determining changes in non-deviative ionospheric absorption and its variations, and one or more lightning flash counters. The six-channel VLF noise measuring equipment (on temporary loan and designed for other purposes) would be replaced by suitable auxiliaries to the ARN-3 to take over its function.

Dopplometers and magnetometers might also be used at this site. However, the use of other electronic equipment, particularly transmitters, will be discouraged.

Test site requirements are:

(1) It must be at least 1/2 km, and preferably 1 km, from all main roads. (Our subsequent measurements show at least 1 km is required.)

(2) It must be 3 km from electrical power distribution lines above 5 kv.

(3) It should have a low horizon (4 degrees or less) in all directions, in order to compare data taken on a CCIR standard ARN-2 whip antenna with data from the CCIR world noise measuring network.

(4) It should be located not more than 2 hours by automobile from the MRDC Electronics Laboratory.

(5) It must be accessible from a main road in all seasons.

(6) It must have a usable area of approximately 300 by 300 meters.

(7) Its surrounding area must be free of structures and man-made activity except normal agricultural operations.

(8) It requires a house, or similar structure, suitable for housing electronic gear. An air-conditioned van with floor dimensions of 8 by 24 feet would be suitable if a house cannot be found. Generator and storage sheds would have to be constructed.

(9) It should be on land controlled by an agency of the Thai government, since permission must be obtained to pour concrete pads, construct sheds, erect antennas, and install electrical power generators.

(10) It should have a man-made noise level considerably lower than that at the Bangkok Laboratory site at all frequencies, VLF and higher, and a reasonable chance of remaining "quiet."

With the above considerations in mind, a study of geographic, thunderstorm, and electrical distribution maps of the area within about two hours driving distance of the MRDC Electronics Laboratory was conducted. Four possible areas were selected from the maps, on the basis of generally good accessibility, low population density, good roads, good weather, and flat terrain.

Diurnal measurements at three possible sites were conducted over a 24-hour period. In November-December 1964, such measurements were conducted by Rangsit Chindaphorn, R. L. Brown, and Lt. Chaikamol Lumjiak, RTAF. To avoid any day-to-day variability, parallel measurement was made at the MRDC Electronics Laboratory in Bangkok. We thus obtained a comparison between all sites, including Bangkok.

As a result of the established criteria, the site chosen is that at Laem Chabang. A schematic map showing the sites investigated is shown in Fig. 6.

b. Determination of Effective Operating Radius of the Lightning Flash Counter

Lightning discharges are known to occur within and between clouds, from cloud to air, and from cloud to ground. In studies of atmospheric radio noise and characteristics of thunderstorms, an instrument known as a lightning flash counter is used to record all types of lightning discharges occurring near the counter. Such counters help determine that component of observed atmospheric noise of local origin.

There are two types of lightning flash counters in common use. One is the ERA counter, with a frequency response from 100 cps to 2 kc. With this type, the intensity of the impulses that actuate the counter varies with distance from source according to an inverse cube law (electrostatic component). The other type of lightning flash counter is the CCIR counter, which has a pass band of 2-40 kc. With this counter, the intensity of the impulses varies with distance from source according to an inverse distance law (radiation component). Since the variation in magnitude of the impulses originating at any given distance is considerable, the effective range is more accurately defined by the inverse cube law (ERA counter) than by the inverse distance law (CCIR counter). Thus, the response of the ERA counter is more truly representative of local lightning frequency, whereas the CCIR counter functions partly on local discharges and partly on VLF atmospherics of more distant origin to give an output more representative of communication interference.

A CCIR counter was constructed for use by the MRDC Electronics Laboratory. It responds to induced pulses of 6 volts from the aerial, and lightning flash data are recorded on a mechanical counter-register. This counter was tested by graduate students of Chulalongkorn University, in the High-Tension Laboratory. Both the sensitivity of the counter and its response to various input pulse amplitudes were investigated and were found to be in accordance with design expectations.

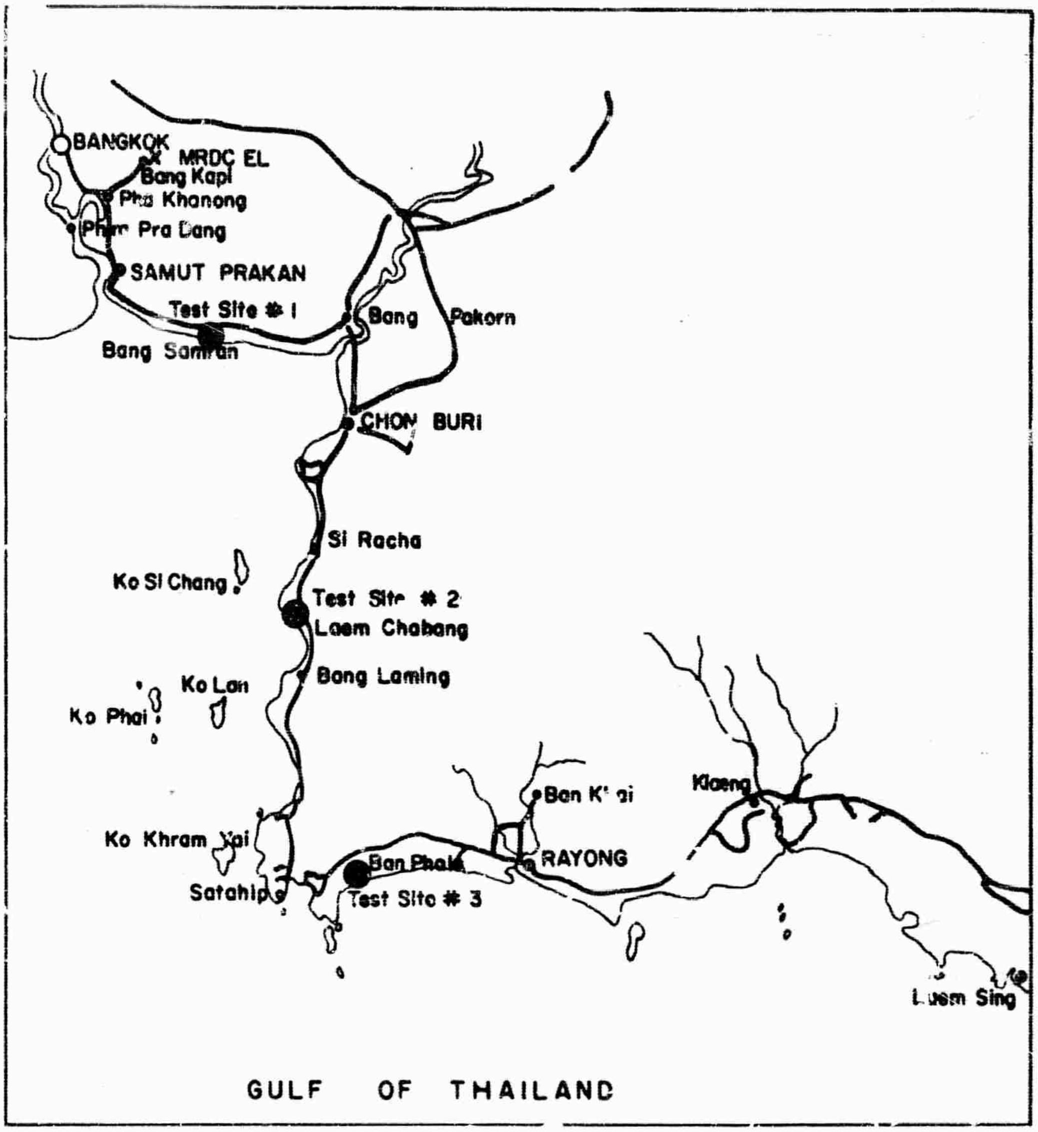

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FIG. 6 A MAP SHOWING THE THREE LOW-NOISE TEST SITES CONSIDERED

The effective operating radius, R, of the counter has been calculated by Dr. E. T. Pierce. Briefly, he used the following procedures:

(1) First, it was estimated that within the acceptance band of the counter, the median impulse from a cloud flash was 8 db less than the median impulse generated by a discharge to earth (see Fig. 7). The individual impulses from both cloud and ground flashes were taken as log-normally distributed around their respective medians with a standard deviation of 6 db.

(2) Using this distribution, the fractions of both types of discharge counted were obtained as a function of the counter threshold setting relative to the median impulse from a cloud flash (see Fig. 8).

(3) The threshold of the Bangkok CCIR-type counter was then determined by using the observational fact that some 10 percent of all flashes at a distance of 15 km operated the counter (see Fig. 9). It was assumed that, as is typical for a tropical country, 90 percent of the discharges occur in the clouds. With the known threshold, the inverse distance law was used to estimate the proportions of cloud and earth flashes counted as a function of distance.

(4) Finally, uniform activity of n flashes per square kilometer was assumed. The total number, N, of flashes counted with the known threshold was obtained by integrating over all distances, and the distance, R, determined by equating N to $\pi R^2 n$. The result gave $R \approx 11$ km. If a zone is defined by the radial distances $r - 1$ and $r + 1$, the area

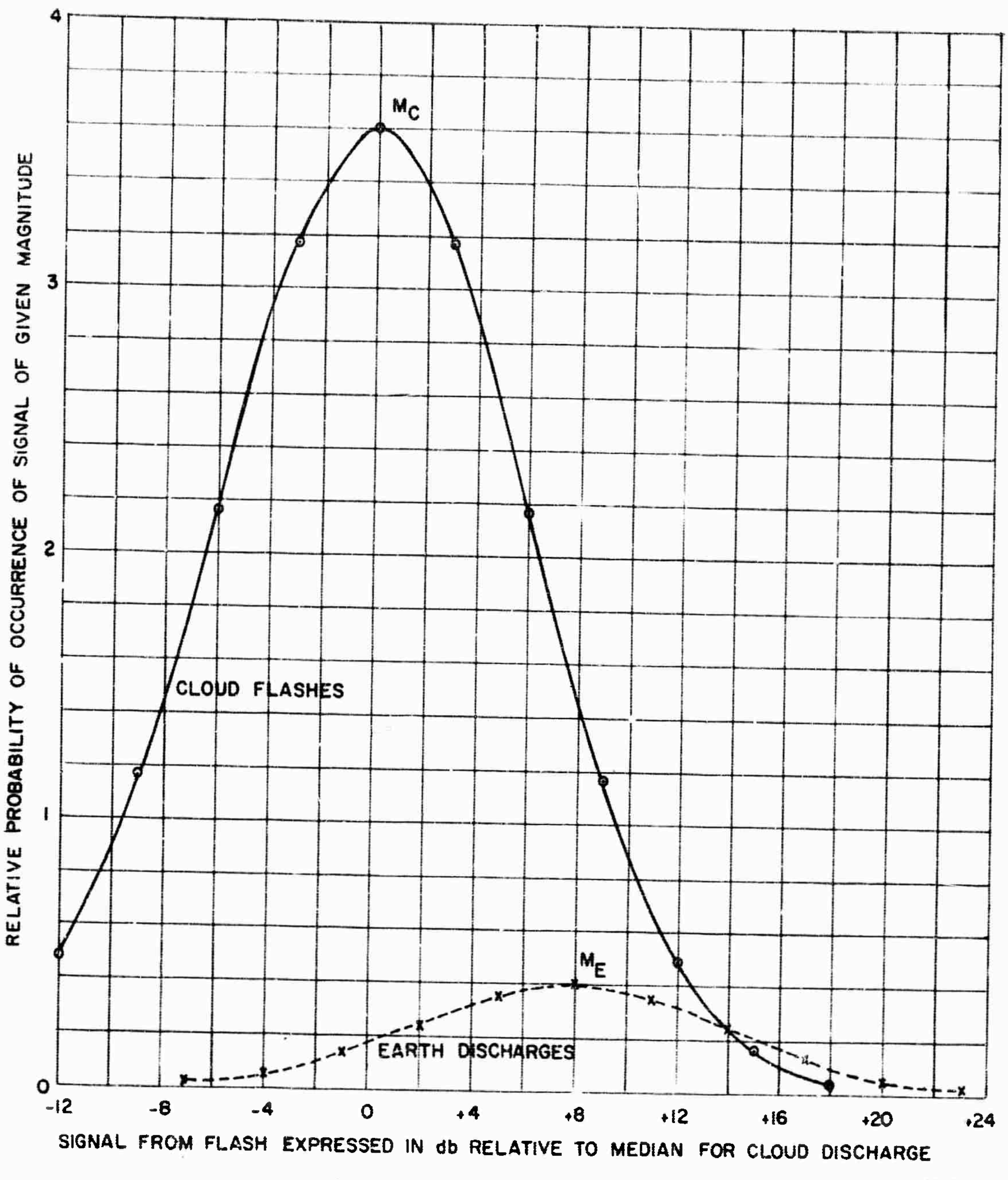

FIG. 7 AMPLITUDE DISTRIBUTION OF VLF PULSE IN FLASHES IN A TROPICAL STORM

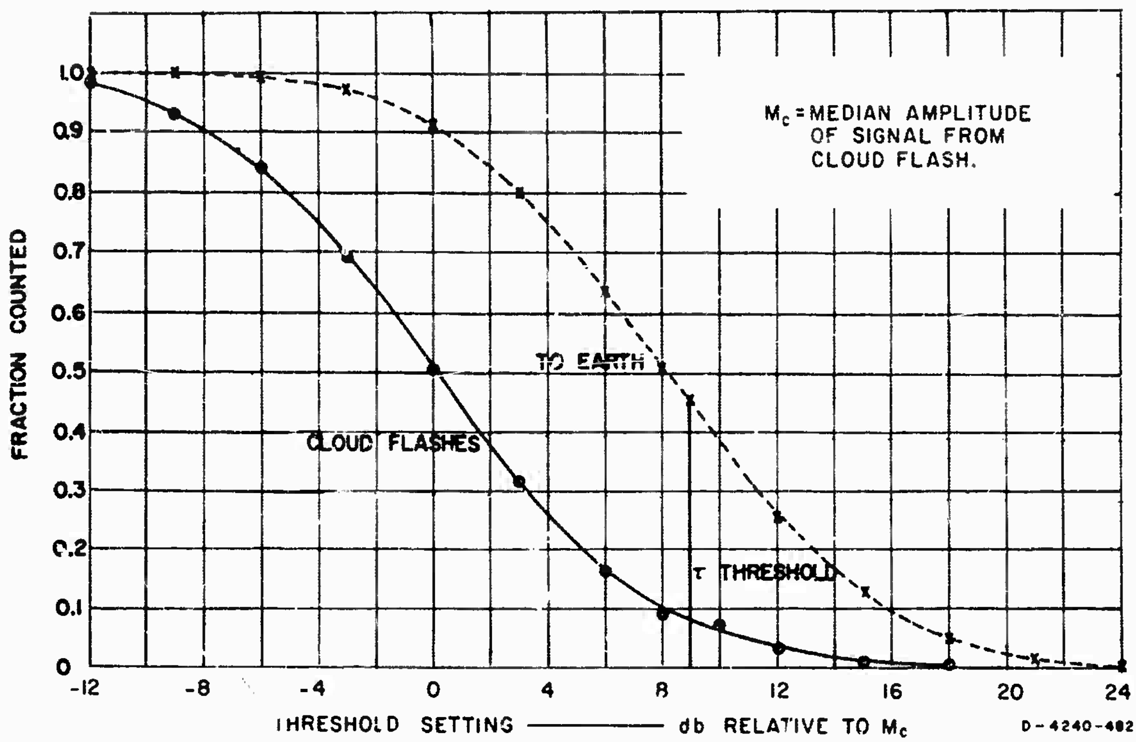

FIG. 8 FRACTION OF DISCHARGES COUNTED AS A FUNCTION OF THRESHOLD SETTING RELATIVE TO MEDIAN IMPULSE FROM CLOUD FLASHES

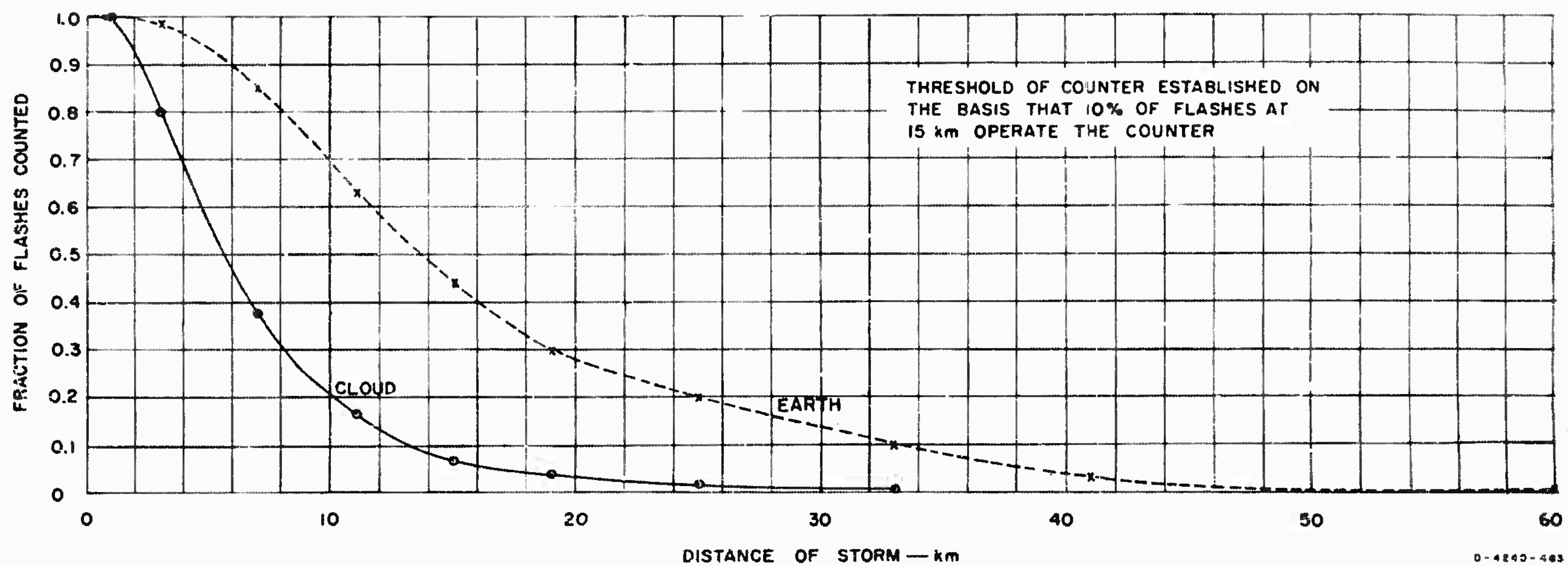

FIG. 9 FRACTION OF DISCHARGES COUNTED AS A FUNCTION OF DISTANCE OF STORM

of the zone is $4\pi r$, and the total flash activity per zone is $4\pi nr$. With the threshold setting of the Bangkok counter, Fig. 10 shows the counts per zone as a function of r. The zone r = 10 would have $40\pi n$ total flashes, $36\pi n$ being cloud discharges; Fig. 10 shows that, from the r = 10 zone, $8\pi n$ cloud flashes and $2.7\pi n$ ground flashes are counted. It is noteworthy that, for flashes to earth, the contributions from zones with r > 11 km are quite large.

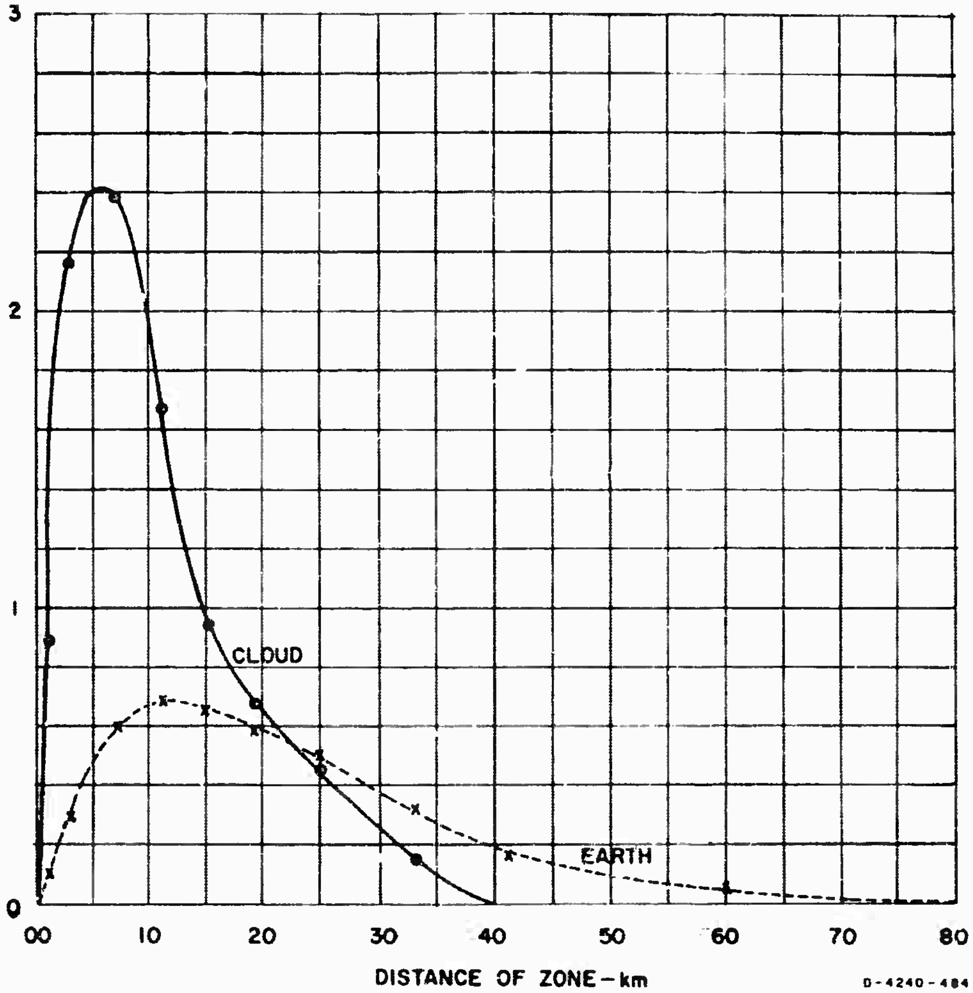

FIG. 10 COUNT CONTRIBUTION BY ZONAL DISTANCE

The CCIR type of lightning flash counter was installed at the MRDC Electronics Laboratory in May 1964 and is still operating. The counter records the number of flashes per day, the information being plotted on a graph that indicates flash activity per day during a period of one month. Sample plots of counts observed at Bangkok were shown in Semiannual Report 3. Additional data will be presented in future reports.

c. Propagated and Local Atmospheric Noise

Atmospheric noise is generated by lightning impulses over a very wide frequency range. The peak radiated fields are produced in the VLF band (3-30 kc), but appreciable signals occur at all frequencies up to 1 Gc and higher. The character of the source signal changes with increasing frequency. At VLF, a lightning flash radiates strong impulses associated particularly with the heavy current surge of the return stroke in the flash to earth. These impulses are separated typically by quiescent intervals which may last several tens of milliseconds. Conversely, at HF (3-30 Mc), the noise is quasi-continuous over the entire duration of the discharge which may approach a second. The largest impulses are only two or three times as great as the general background. Over the MF frequency range, the structure of the source signal is intermediate. There is an almost-continuous background extending over the entire time that discharge processes are occurring, but there are also super-imposed impulses, sometimes as large as ten times the background.

Above approximately 5 kc, the fields radiated by lightning decrease with increasing frequency. For example, at 400 kc, the source field strength is about half (6 db down) that at 200 kc.

After their production at the lightning flash, the noise signals propagate outwards. Generally speaking, the signal strength will decrease with increasing distance, but in a dispersive (frequency-dependent) manner. Thus, the original source spectrum is modified by propagation.

Atmospheric noise as measured at any particular station will represent a combination of signals from thunderstorms at many ranges. At most times, however, even in a tropical country such as Thailand, the greatest contribution to the mean observed atmospheric noise level comes from distant storms. As an estimate, Thailand has about 100 thunderstorm days per year, and, during perhaps 6 hours of each day, noise records are dominated by close lightning. Thus, about 7 percent of the time, local storms are the most important noise source; during the remaining 93 percent of the time, distant storm centers are the significant generators. Most available noise information relates to average values which inevitably reflect this predominance, in the time sense, of distant storms. Communication circuitry is thus designed essentially to accommodate the noise levels due to the distant activity which, although often sufficiently high to be a nuisance, is rarely intolerable. Conversely, the violent increase in radio noise accompanying a local thunderstorm can be catastrophic in its effects on communications.

Levels of propagated and local atmospheric radio noise are indicated on the six-channel VLF noise recorder. A comparison of noise levels on a quiet day (no local storm activity) with a condition of local atmospherics is shown in Fig. 11(a). Data for 18 June represent a quiet day, with the usual afternoon rise at 1600 hours, while 17 June was a day with intense local atmospherics, reaching a peak of F_a* = 123.7 db at 1300 hours.

The graph showing data taken at 200 kc, indicates a 16-db increase in noise level due to a local storm as compared with a quiet day.

---

* F_a = Effective Antenna Noise Figure = External Noise Power Available from an Equivalent Short, Lossless, Vertical Antenna in db Above ktb.

F_a in db is related to the rms field strength at the antenna by the following equation:

$$E_n = F_a + 20 \log_{10} f_{Mc} - 65.5 \quad ,$$

where:

E_n = the equivalent vertically polarized ground wave rms noise field strength in db above 1 μv/meter for a 1 kc bandwidth.

f_{Mc} = the frequency in megacycles/second.

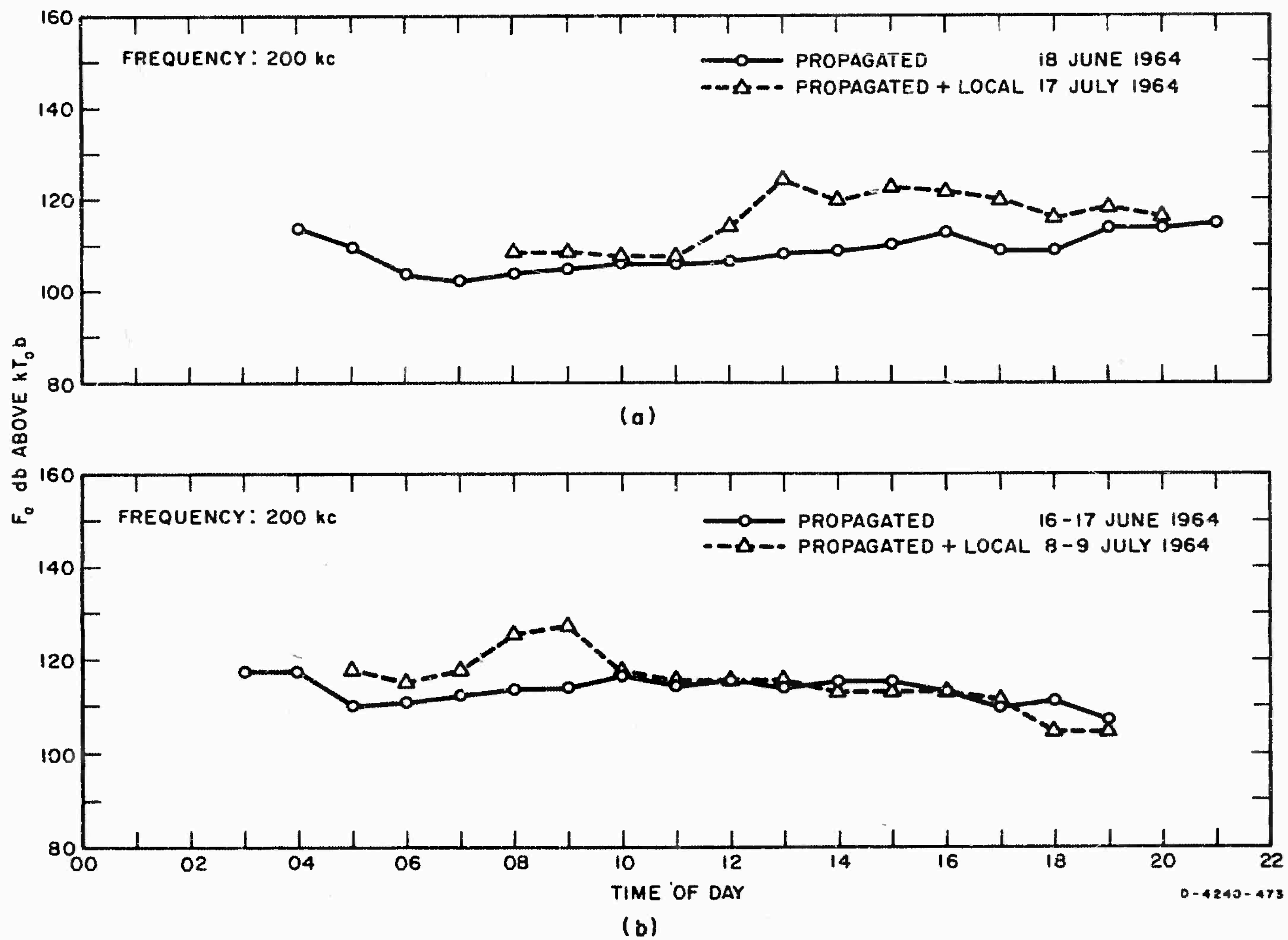

FIG. 11 COMPARISON OF RELATIVE NOISE POWER DUE TO PROPAGATED AND PROPAGATED PLUS LOCAL ATMOSPHERICS AT 200 kc

Figure 11(b) is another example of the same type of comparison (at 200 kc), except that the noise peak occurs at a different time of day.

As an example of the diurnal variation in the median hourly value of measured noise level at the MRDC Bangkok Laboratory, there was a 16-db difference between the nighttime propagated noise level and the low daytime level at 200 kc for the month of May 1964.

The six-channel VLF noise recorder is shown in Fig. 12.

d. HF Spectrum Occupancy Experiment

A brief spectrum occupancy experiment was conducted at the MRDC laboratory in Bangkok. The purpose of the experiment was to gather data on the 2-12 Mc frequency spectrum usage at Bangkok, particularly to observe radio stations and man-made interference, and to experiment with and evaluate different methods of conducting this type of measurement.

The data collected during this experiment gave a general idea of the 2-12 Mc spectrum usage near Bangkok and some of the characteristics of the stations occupying this frequency spectrum.

In the data collection method selected, a motor and gear reduction system tuned a receiver while the receiver output was recorded on a strip chart recorder. This method automatically produces a plot of amplitude vs. frequency and therefore gives a useful picture of the spectrum. By breaking each 1-Mc band of the frequency spectrum into four segments, one graph can be used to display each 1-Mc band of the spectrum.

The frequency is marked at every 10-kc point of the first 250-kc scan with the marker pen. The signal level is calibrated with a signal generator at the start of each 250-kc scan.

The following equipment was used in this experiment:

(1) One R390-A/URR Receiver

(2) One Offner Dual Channel Recorder

(3) One Hewlett-Packard 606A Signal Generator

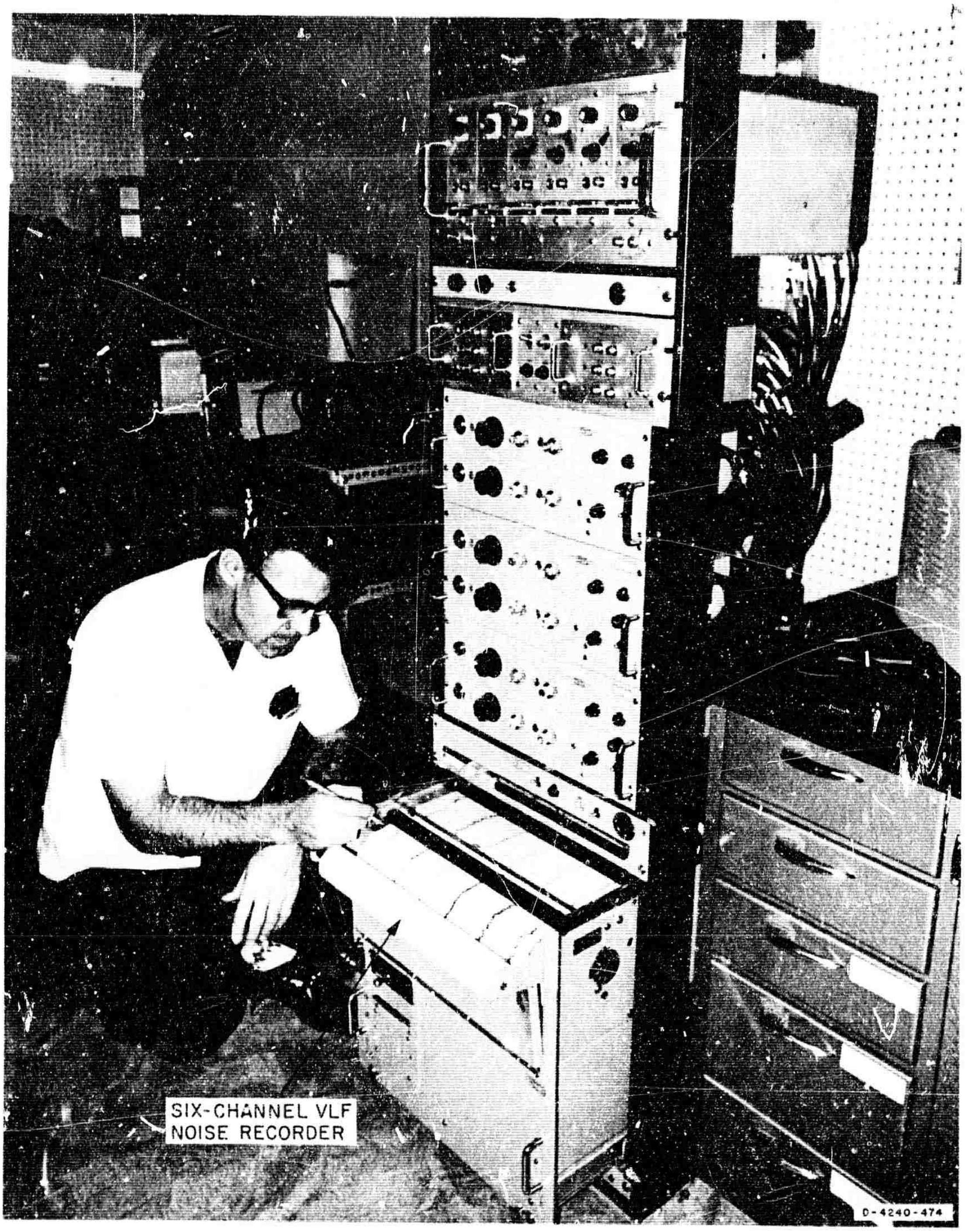

FIG. 12 SIX-CHANNEL VLF NOISE RECORDER

(4) One 15-foot whip antenna

(5) One ac synchronous motor with 0.5 rpm gear reduction drive.

Figure 13 is a sample spectrum occupancy chart. The chart covers 1 Mc of the spectrum. Frequency is read on the horizontal axis; the signal level is read on the vertical axis. The 1-Mc band displayed on the chart is broken down into four 250-kc scans. The top scan covers 0-250 kc; the second scan covers 250-500 kc; the third scan covers 500-750 kc; and the fourth scan covers 750-0 kc of the next higher band. The signal level is indicated in decibels, with 1 μv used as the reference. This is the level delivered to the receiver input, and does not take into consideration the effects of antenna mismatch, etc. Charts were made between the hours of 1200 and 1600, local time, but not all on the same day, for the 2-12 Mc frequency range.

Other charts were similarly made to indicate variation of spectrum occupancy with time of day for various frequency bands, variation in results with type of receiving antenna, variation of occupancy from weekday to week end, and presence of broadcast band station harmonic radiation (Fig. 14). Some of the harmonics of the stations in the top 250-kc scan were identified by ear; these are shown in Fig. 14 by the arrows pointing between the fundamental frequencies (top scan) and the harmonic frequencies (two lower scans).

The method used in this brief experiment worked well. Future experiments could be conducted to give adequate results according to the experience gained in this experiment. With proper receiver IF bandwidth, some types of station modulation may be distinguished from the character of the recordings.

Figure 15 shows received signals for the afternoon period. The highest density of stations occurs in the 8 Mc region. Figure 16 shows that station density is lowest at 1400, local time, with peaks at 0800 and 2000. Density is consistently greater in the 6.5-6.75 , 11.5-11.75, and 2.5-2.75-Mc bands. No clear evidence exists for any weekday to week end change in station density, as shown in Fig. 17.

LOCATION: BANGKOK. ANTENNA: WHIP
DATE: 7/13/64 LOCAL TIME: 1200

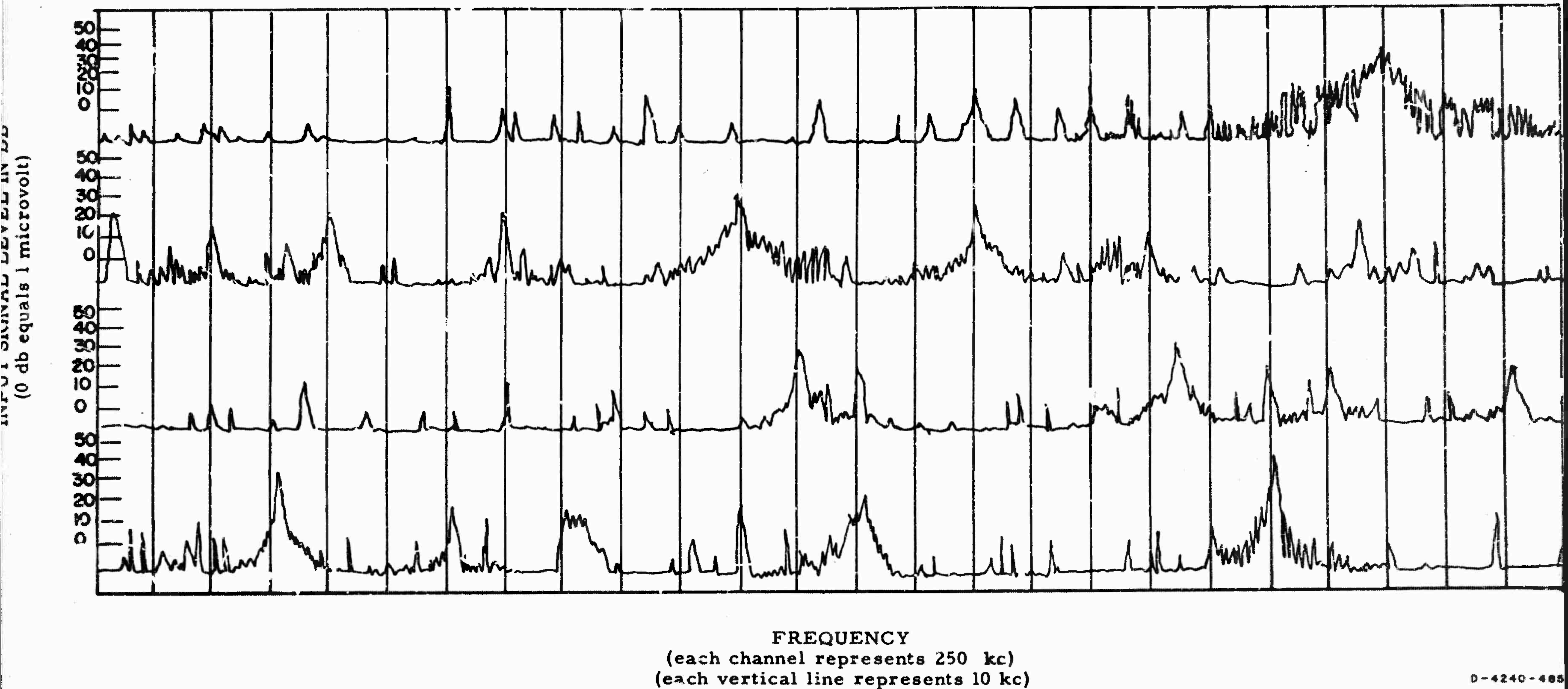

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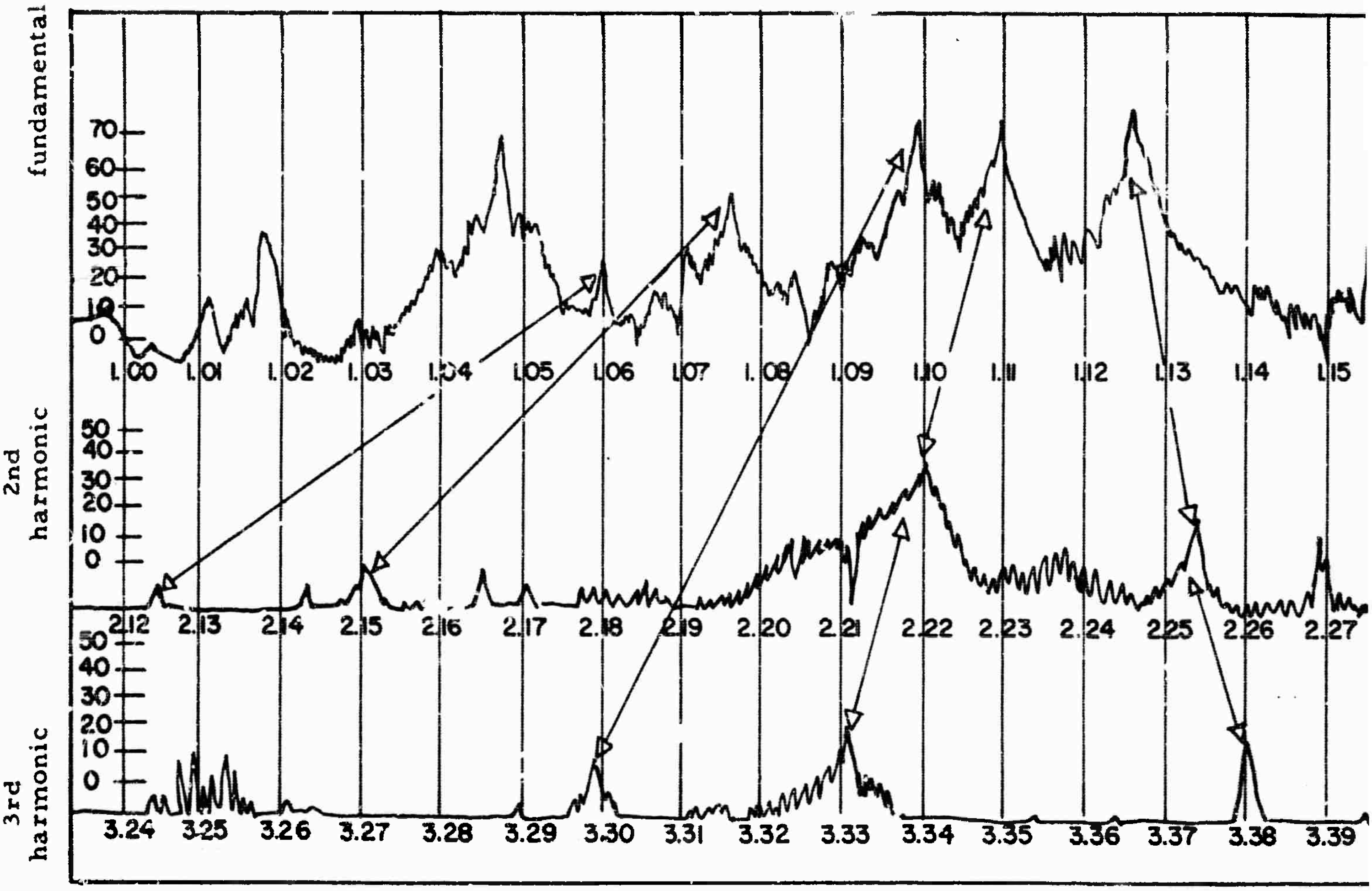
FIG 13 FREQUENCY SPECTRUM CHART OF 2-3 Mc BAND

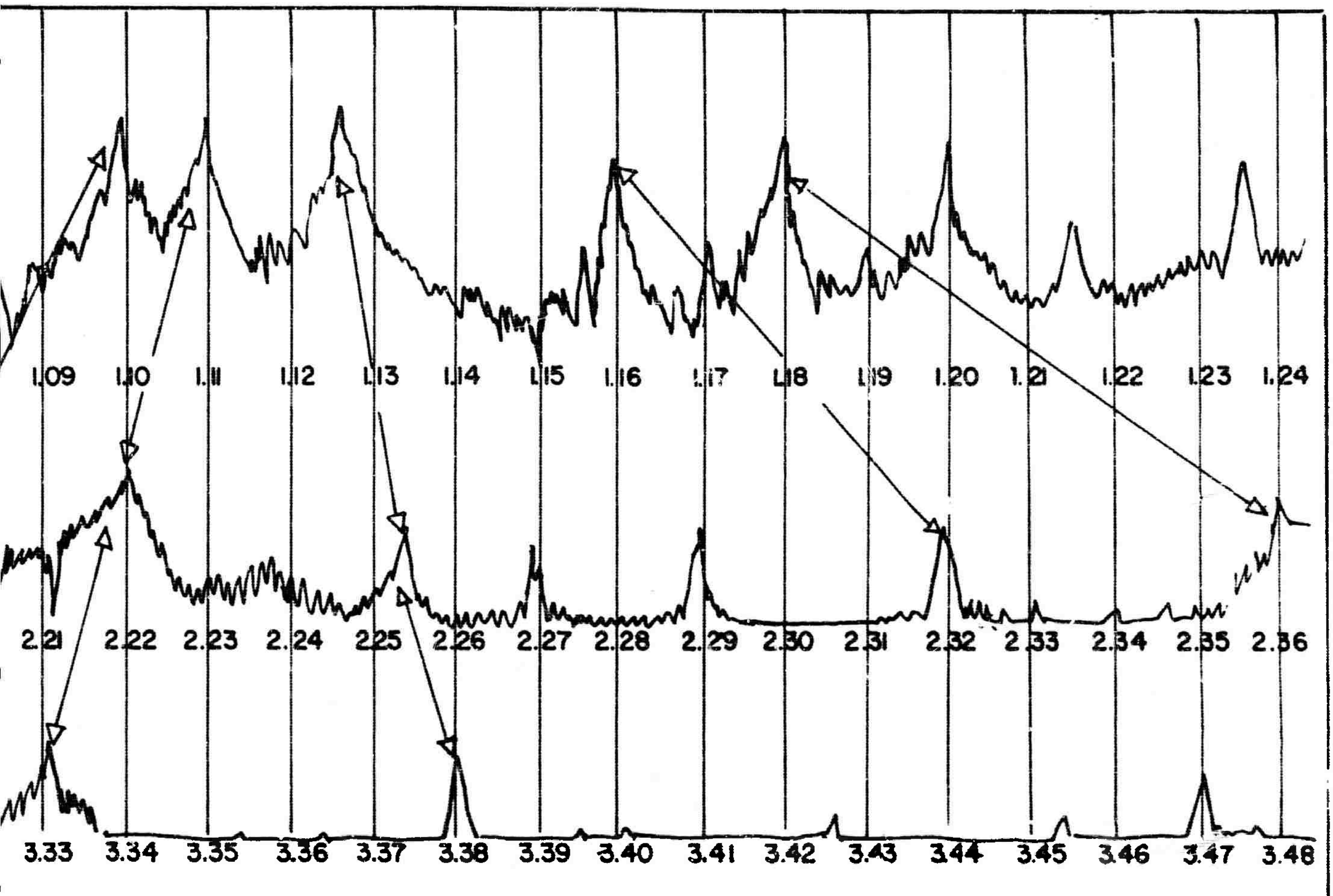
HARMONIC RADIATION SAMPLE
LOCATION: BANGKOK. DATE: 7/22/64. TIME:



FREQUENCY
(eac! vertical line represents 10kc)

FIG. 14 FREQUENCY SPECTRUM CHART OF 1.0· 1.24 Mc B

C RADIATION SAMPLE
N: BANGKOK. DATE: 7/22/64. TIME: 1300. ANT: WHIP



FREQUENCY
(each vertical line represents 10kc)

D-4240-422

REQUENCY SPECTRUM CHART OF 1.0-1.24 Mc BAND

2

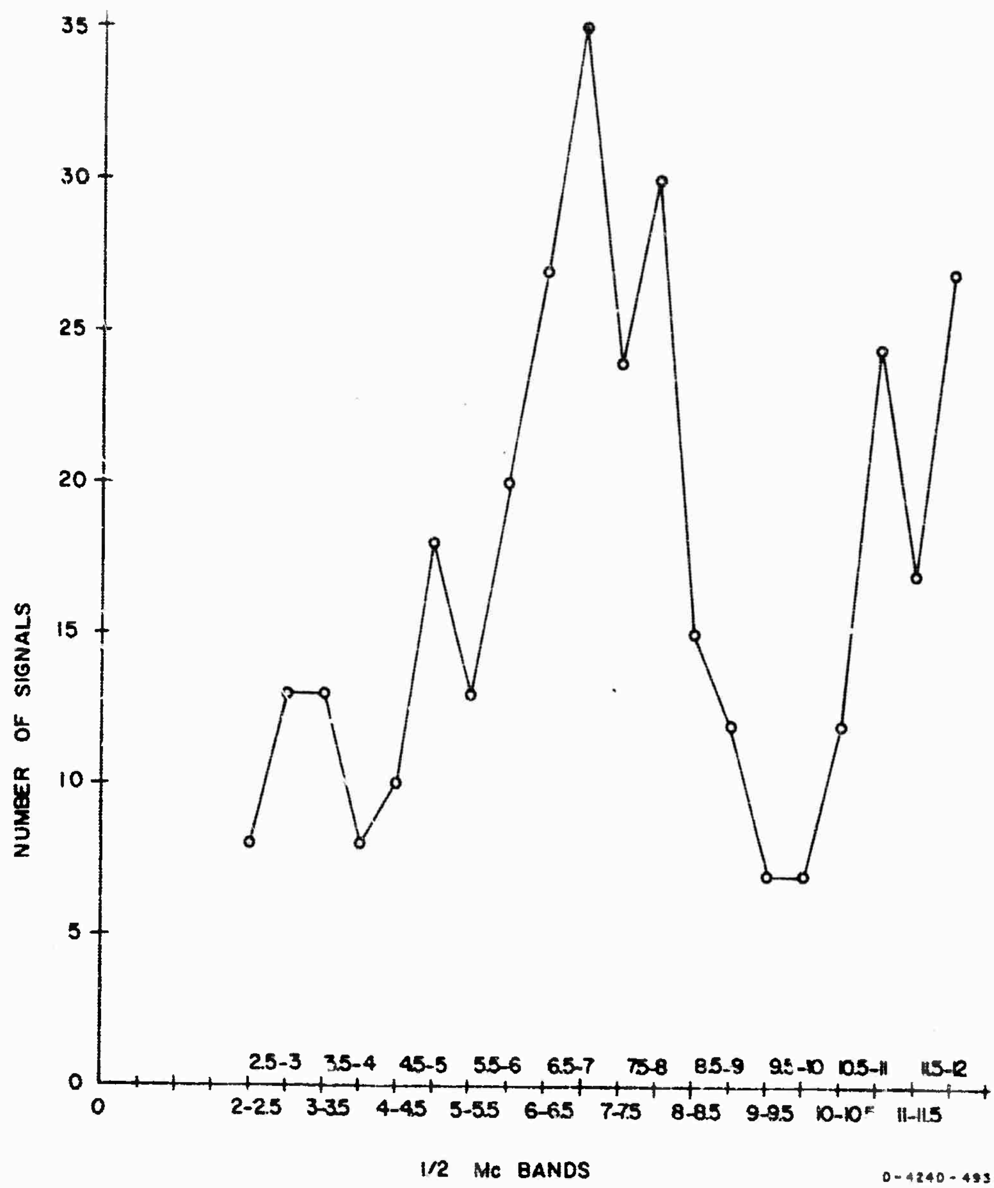


FIG. 15 NUMBER OF SIGNALS GREATER THAN 10 db ABOVE 1μv PER 1/2-Mc BAND, 2-12 Mc AT BANGKOK

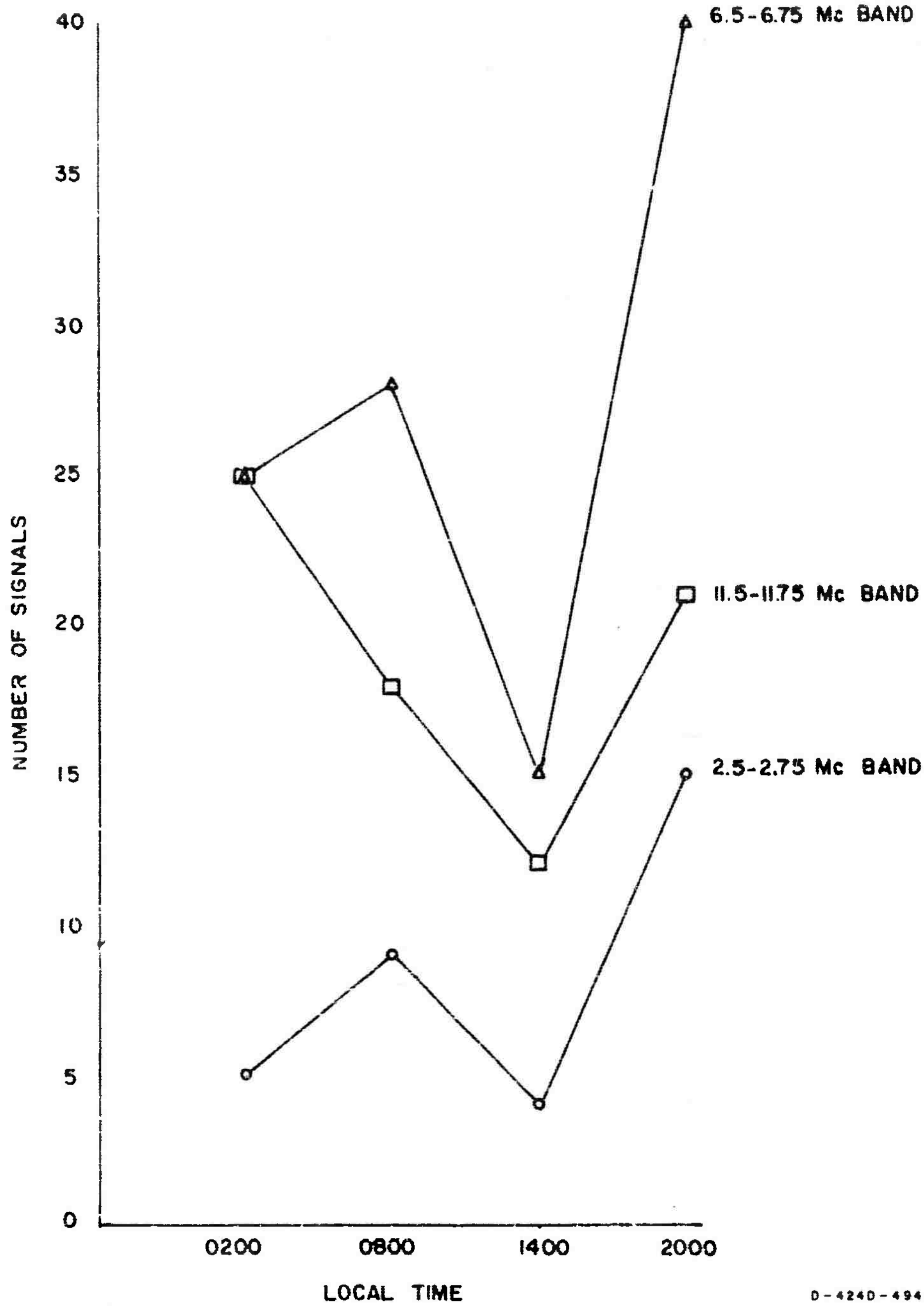


FIG. 16 NUMBER OF SIGNALS GREATER THAN 10 db ABOVE 1μv PER 1/4-Mc BAND vs. TIME OF DAY

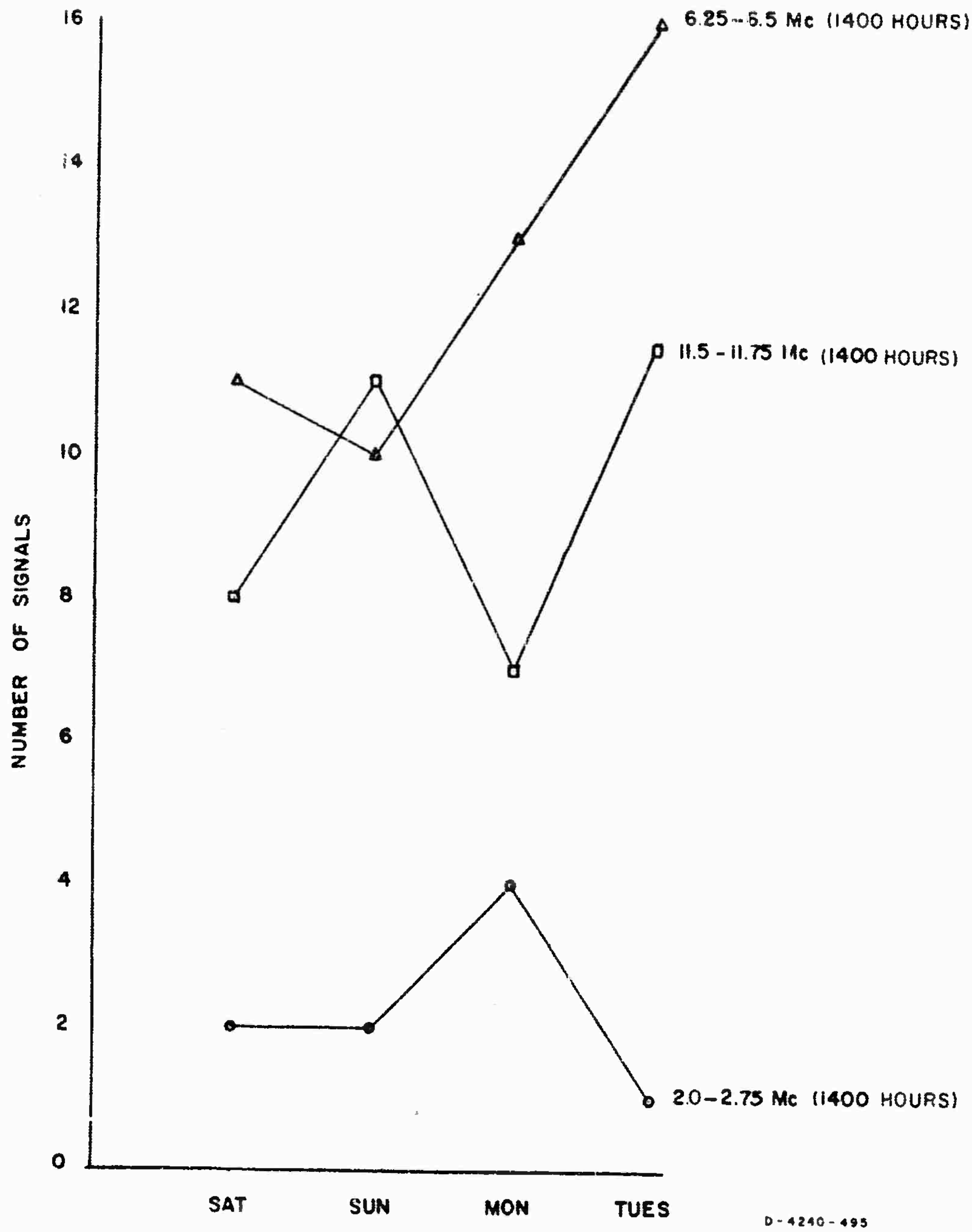


FIG. 17 NUMBER OF SIGNALS GREATER THAN 10 db ABOVE 1 μv PER 1/4-Mc BAND vs. DAY OF THE WEEK

e. ARN-2/ARN-3 Noise Measuring Equipment

A most useful noise measuring device is the ARN-3 noise recorder. This type of equipment operates automatically; provides useful, standard data (comparable to CCIR data); and its measurements will apply to large areas of Thailand.

A new, specially-designed ARN-3-type, RF-noise-measuring device is being acquired to provide long-term, reliable noise measurements, as well as other special test data. The data obtained by use of such an instrument would be supplementary to and compatible with existing world-wide noise data. Also, adequate data on the limits of man-made noise in the Bangkok area should be collected. This can be done by using a second (portable) ARN-3. Construction of the ARN-3-type equipment awaits action on SRI Proposal No. ELU 64-140.

The literature survey of application of ARN-2-type data to radio systems has resulted in collection of a considerable number of papers on this subject. These have been studied, forwarded to Bangkok, and are being used in studies there in preparation for analysis of the data to be collected during the ARN-3 noise measurement program.

The noise direction finder, together with world thunderstorm maps and radio maps, provide information on general seasonal trends regarding noise arrival direction. However, world thunderstorm activity is so heterogeneous that discrimination against higher noise levels from certain azimuthal directions at HF does not appear very practical, except possibly during certain seasons. Benefits that may be derived from utilizing antenna directivity to increase signal-to-noise ratio will be indicated by noise angle-of-arrival tests scheduled to be performed at the low-noise site at Laem Chabang, employing the ARN-3 to give both relative and absolute signal and noise values. These tests will check both azimuth and elevation angle of arrival as a function of time of day and season, as well as polarization effects.

Design of receiver modifications--to enable the ARN-3 equipment to accept VLF (3, 10, 27, and 160 kc) and thereby replace the

6-channel VLF recorder--has been accomplished. The standard ARN-2 antenna has been obtained (base insulator loaned by the National Bureau of Standards, CRPL, Boulder, Colorado) and shipped for assembly at the low-noise site.

f. Noise Reduction Experiment Employing Balun on 4-Mc Dipole

When coaxial cable without a transformer is used as the transmission line for a horizontal dipole antenna, an unbalanced system results, and vertically-polarized noise may be picked up by the feedline and added to the desired receiver input signals. Use of a transformer between the end of the coaxial cable and the dipole feed results in a balanced system.

A brief experiment was conducted at the Bangkok laboratory to determine the possible improvement in signal-to-noise ratio by the use of a balun transformer with a 4-Mc horizontal dipole antenna employed for receiving.

In the experiment, a transformer and relay arrangement was installed at the center of a dipole antenna, elevated about 30 feet, such that the transformer could be switched in or out of the system from the laboratory, located just at the edge of Bangkok. The ratio of a desired 4-Mc signal arriving at high angle to the combined ambient, man-made, and atmospheric noise was increased about 10 db when the transformer was used, in contrast to the unbalanced system. Figure 18 shows a schematic of the system utilized. Insertion loss of the balun was about 1 db at 4 Mc. Thus, the net improvement for a system using dipoles with baluns for both transmitting and receiving would be 9 db for this example.

Use of such transformers with horizontal dipole antennas should reduce receiver noise levels caused by vertically-polarized, man-made or atmospheric noise, and should be especially useful with HF man-pack sets since these sets are not easily grounded. The insertion loss of properly designed ferrite core baluns should be the order of 1 db or less, and consequently should not degrade system performance appreciably.

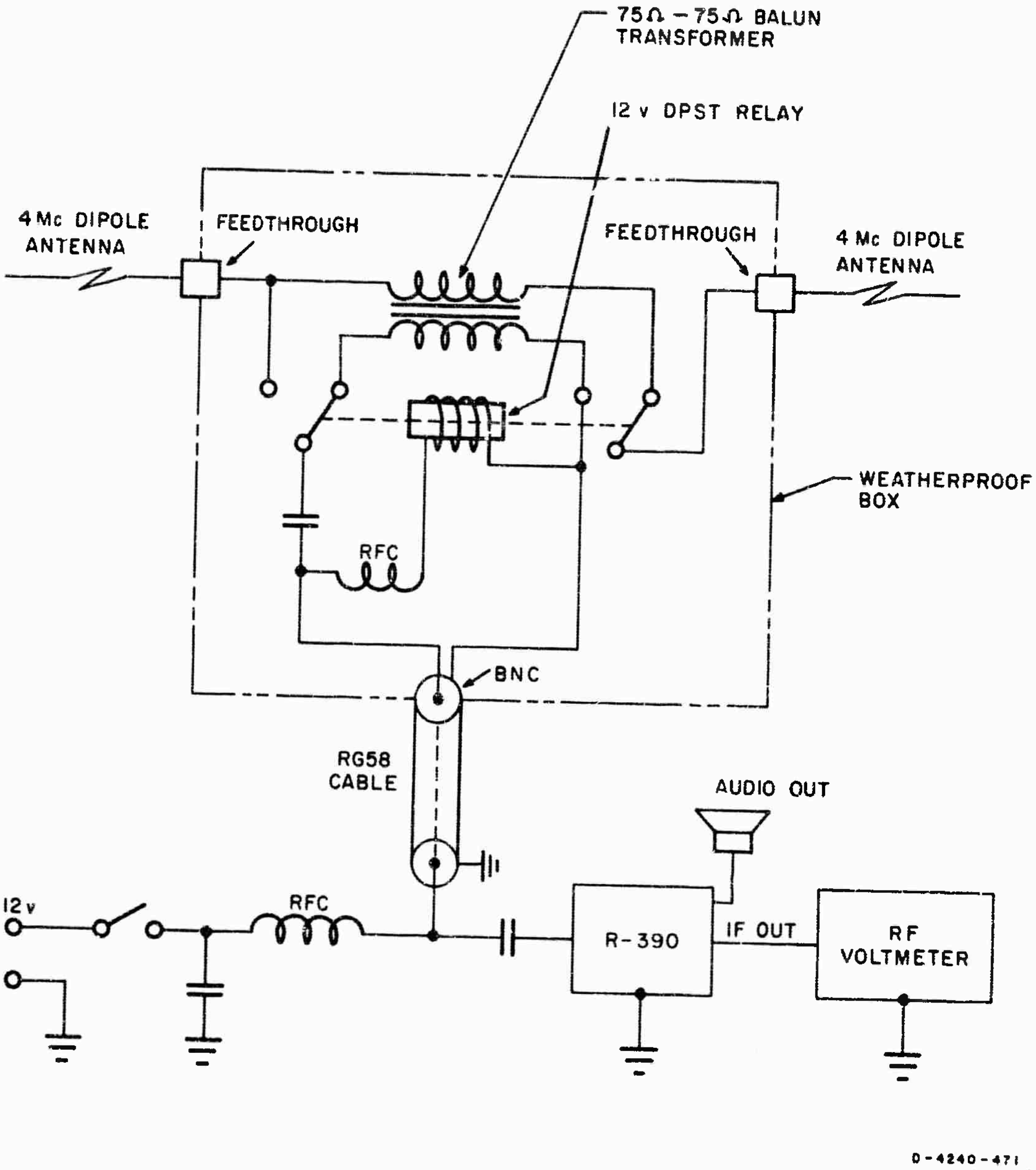


FIG. 18 NOISE REDUCTION EXPERIMENT SCHEMATIC DIAGRAM

3. Subtask 3--Antenna Orientation Investigations

A series of HF antenna orientation measurements were conducted from December 1963 to October 1964. These measurements were based upon the magneto-ionic theory with a view to optimizing the orientation of a linearly-polarized antenna, such as a half-wave dipole, for short-range communication via the ionosphere near the geomagnetic equator. The practical application together with its limitations has been considered. Continuous-wave measurements (performed with the goal of determining a suitable wave mode of propagation and hence the desired orientation of horizontal dipoles) demonstrate the superiority of the ordinary wave for overall performance over a major part of the day when communication traffic is normally active. Pulse measurements have confirmed the results of the CW measurements and have given additional information on the coupling between the ordinary and extraordinary modes, amplitude and phase stability of received waves, and ionospheric layers supporting these waves. Overall results of the CW and pulse tests suggest that, although the optimum orientation of horizontal dipoles for both transmission and reception is parallel to the earth's magnetic field, communication performance may be further improved by polarization diversity reception. Use of an additional horizontal dipole aligned orthogonally to the north-south dipole permits use of the extraordinary mode whenever the ordinary wave fades or becomes inferior. Polarization diversity and its properties have been investigated by radio-teletype (RTTY) measurements, which afford a ready means for assessing performance of various antenna configurations from a RTTY systems viewpoint. Overall results of this study produce a simplified method of planning HF communication network antenna design for Thailand.

The antenna orientation effort has been conducted in three phases: CW, pulse, and diversity tests. Initial CW test efforts and results were discussed in Semiannual Report 3.

Further CW data analysis, pulse tests and results, and diversity tests and results are described in detail in a special technical report now nearly complete.

The additional CW data analysis has considered the following factors:

(1) Diurnal variation

(2) Mode coupling

(3) Fading characteristics

  (a) Number of fades per minute

  (b) Duration of fading

  (c) Severity of fading

(4) Noise at the receiver input

(5) Benefits of diversity.

a. <u>Pulse Measurements</u>

Use of the pulse-recording method enables one to distinguish various modes of propagation, including virtual heights of reflection. Amplitude stability and a measure of multipath and phase stability can be obtained from pulse data. The ability to obtain information on these factors is the decided advantage of the pulse method over the CW method.

The pulse test was designed with a view to validating certain aspects of the magneto-ionic theory leading to the optimization of antenna orientation and obtaining ranges within which the findings may be used. Figure 19 shows the block diagram of the pulse transmitter utilized.

b. <u>Radio-Teletype Measurements</u>

A preliminary study of CW and pulse data indicates that, although one pure characteristic wave is more suitable for ionospheric propagation during a specific time of day, the communication may be further improved by the use of a polarization diversity reception system. Such a system might even be better than the standard space-diversity setup in common use. One polarization-dependent system uses crossed horizontal dipoles (one dipole oriented parallel to, and the other dipole oriented orthogonal to, the geomagnetic meridian) and is referred to as polarization diversity. Another system, referred to as hybrid diversity,

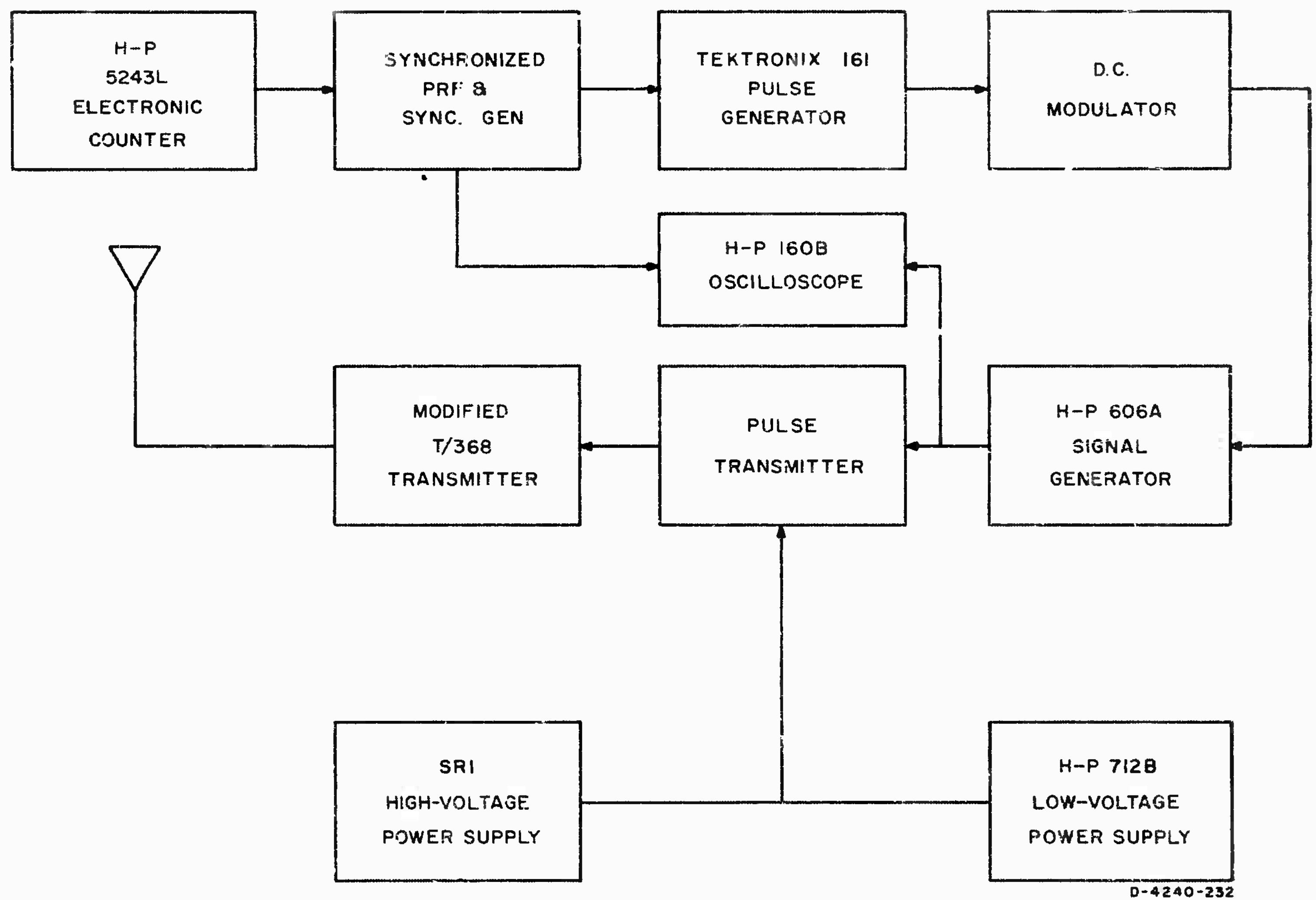


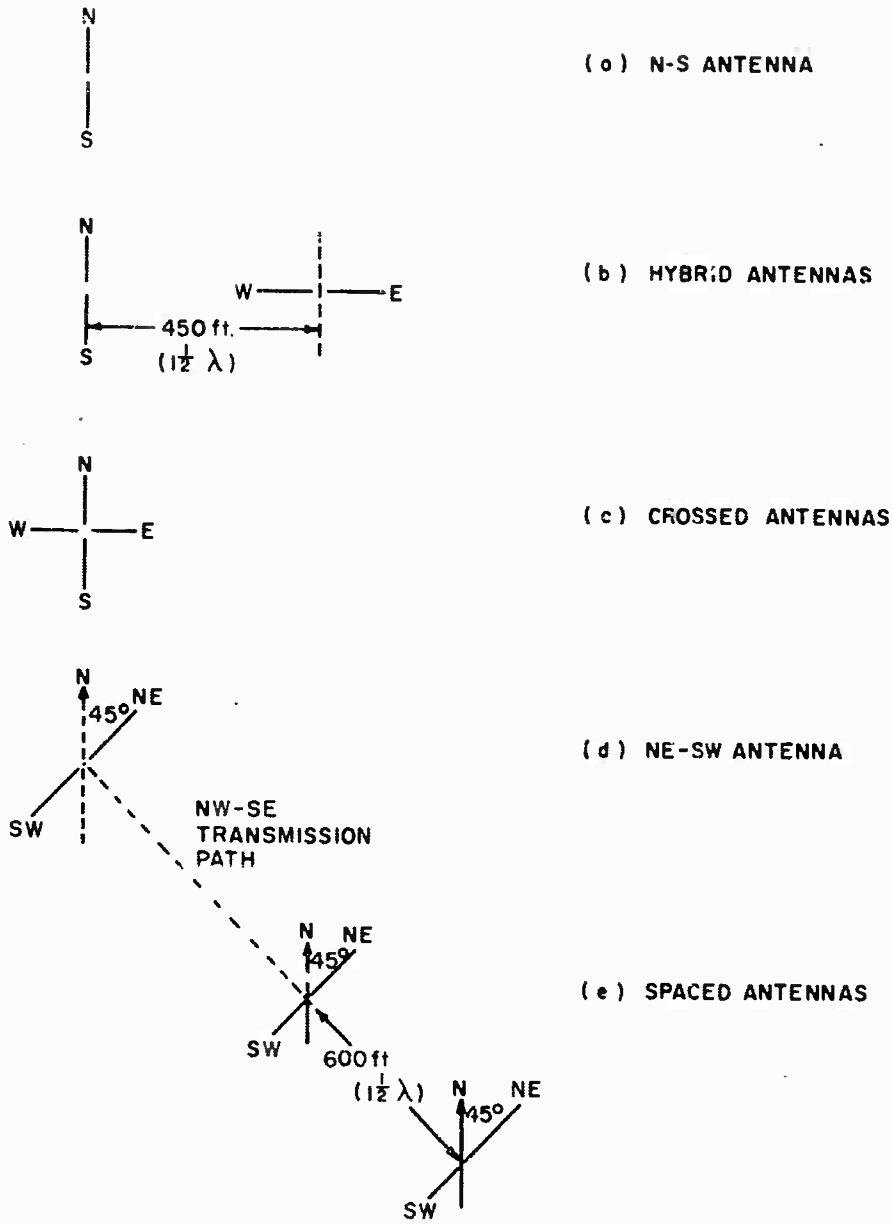
FIG. 19 INSTRUMENTATION BLOCK DIAGRAM FOR PULSE TRANSMISSION

attempts to combine the advantages of polarization diversity (using N-S and E-W horizontal dipoles) with the advantages of space diversity, with the two orthogonal dipoles spaced a certain distance apart. This distance, typically about two wavelengths for a space-diversity system using parallel dipoles, might be reduced by orientation of spaced antennas for polarization diversity with equivalent results.

A short test with radio-teletype equipment was designed to obtain an indication of the relative performance of these diversity systems for use on short ionospheric paths near the magnetic equator. Brief measurements were performed at 3.4 Mc over the Bangkok-Ayutthaya circuit with AN/GRC-26(A) radio teletype sets to investigate and compare the performance of the hybrid diversity reception with the reception of one characteristic wave, the ordinary. Tests were conducted in both directions, with little difference in time, so that the S-to-N and N-to-S transmissions might be directly compared.

Various types of polarization diversity reception were investigated and compared with the usual space diversity reception of radio-teletype over the NW-SE Bangkok-to-Cholburi circuit, approximately the same distance as that of the N-S and S-N Bangkok-Ayutthaya circuits (66 km). Spacing for the spaced antennas was 600 feet, as recommended in U.S. Army Technical Manual, TM 11-5820-202-10. At 3.4 Mc, this corresponds to two wavelengths. Spacing for the hybrid antennas was 450 feet (about 1.5 wavelengths). Antenna systems used are shown in Fig. 20. The Bangkok-to-Cholburi test circuit was chosen because the NE-SW antenna, besides being the recommended space-diversity-system antenna, also launches the ordinary wave, as well as the extraordinary, and is thus suitable for investigation of polarization-diversity schemes using both waves.

The results of these tests, which involved the transmission of a simple message (e.g., RY) and the counting of errors, are shown in Fig. 21. In this brief test, the polarization-diversity system was superior to the other systems tested for most of the day.



ANTENNA SYSTEMS FOR:

(a) ORDINARY-WAVE RECEPTION OR TRANSMISSION
(b) HYBRID SPACE-POLARIZATION DIVERSITY RECEPTION
(c) CROSSED-POLARIZATION DIVERSITY RECEPTION
(d) ORDINARY- AND EXTRAORDINARY-WAVE TRANSMISSION
(NOTE: MAGNETIC DECLINATION OVER THE TEST AREA $<1°$)
(e) SPACE DIVERSITY RECEPTION FOR THE BANGKOK-TO-CHOLBURI PATH (N135°S)

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FIG. 20 DIVERSITY ANTENNA SYSTEMS

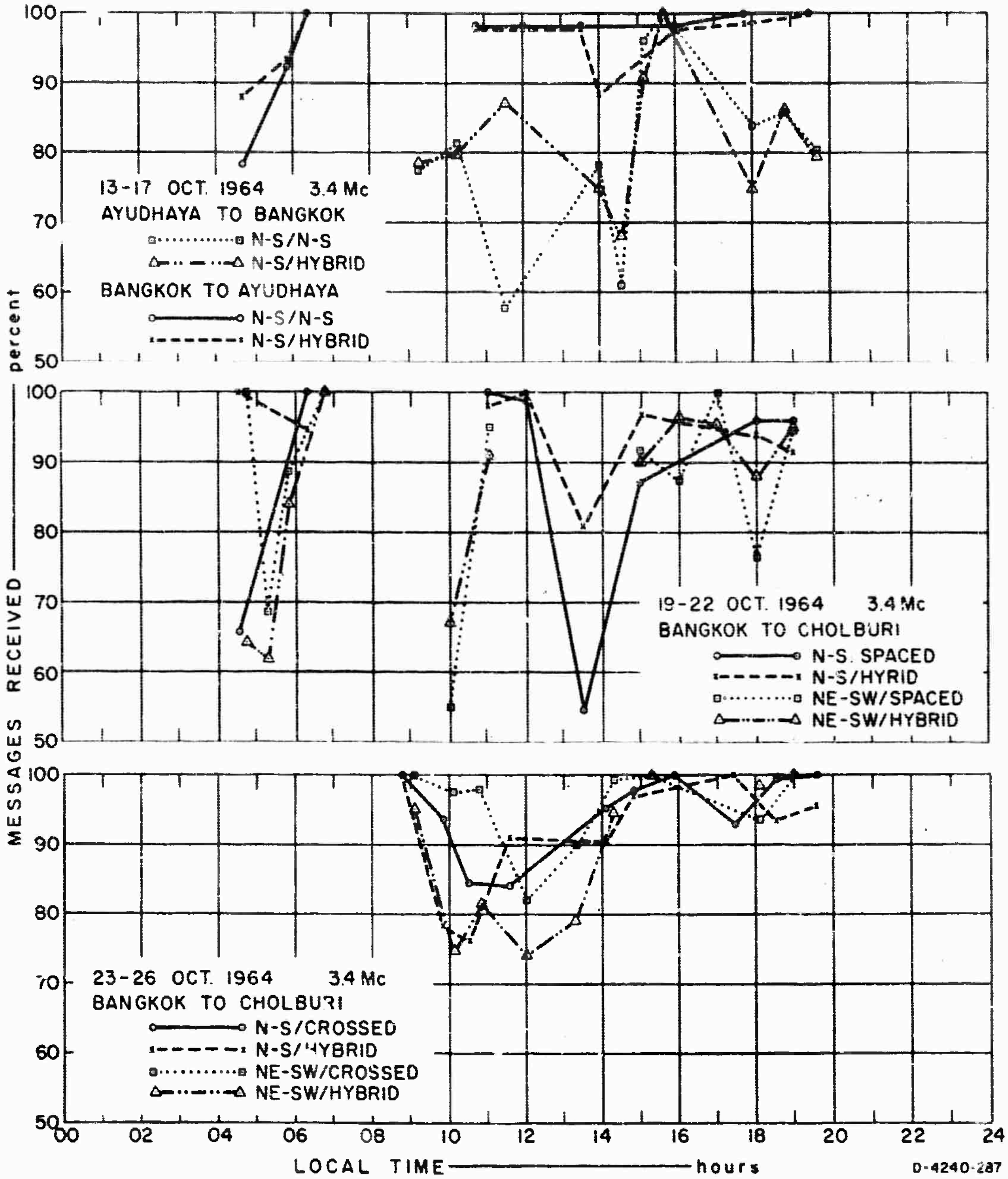

FIG. 21 COMPARISON OF TELETYPE DIVERSITY SYSTEMS

c. Summary Remarks

Final data analysis is nearly complete on the dipole orientation work. A decided advantage has been shown for circuits using N-S oriented dipole antennas relative to those employing conventional broadside orientations. Also, diversity circuits using magnetically oriented, crossed-dipole antennas that are closely spaced have receiver outputs with lower amplitude correlation and lower teletype error rates than conventional spaced-diversity receiver outputs.

A comprehensive technical report is being prepared to describe in detail the measurements, their results, and conclusions derived from the experiment.

To indicate some of the consequences of this subtask, the following information on an application of dipole orientation in Vietnam is extracted from the CDTC-V Quarterly Report for the fourth quarter of 1964:

> The antenna installation in the CDTC-V compound has been completed. A north-south doublet has been installed and is being used on the Bangkok circuit at 320° azimuth and on the Buon Brieng circuit at a 20° azimuth. While no qualitative data have been recorded, the Buon Brieng circuit has been checked with both N-S and broadside antenna orientation. A six db improvement in received signal strength when using the N-S antenna has been noted on the KWM-2A S-meter at both stations.

4. Subtask 4--Measurements of Ground Constants

The ground constant measurement program was described in Semi-annual Report 3. Little additional work was accomplished during the first part of this reporting period due to the rainy season. Preparations were made for a few additional measurements in Northeast Thailand which were started in March 1965.

Reviewing briefly, the two techniques employed are the wave tilt method and the field strength method.

The wave tilt method involves aligning a linear antenna for minimum received signal, measuring the antenna angle relative to mean ground level (wave tilt angle required to satisfy the boundary conditions) and using the relationship,

$$\tan \theta \approx \frac{1}{\sqrt{\epsilon_r}} ,$$

to calculate the relative dielectric constant, where,

θ = wave tilt angle

ϵ_r = relative dielectric constant.

This equation holds for $\omega\epsilon >> \sigma$ where $\epsilon = \epsilon_r \epsilon_o$, ϵ_o = permittivity of free space, σ = conductivity. Consequently, the technique is of more use at the higher frequencies. The wave tilt method for measuring dielectric constant has worked well for measurements made on dry soil; however, the resolution is very poor for such highly conducting earth as wet soil, where the wave is virtually untilted (tangential electric field must be zero to satisfy boundary conditions for a perfect conductor; i.e., zero tilt). The wave tilt method tells the average dielectric constant in a relatively small area near the receiving antenna. This is especially useful in determining the ground reflection coefficient used in antenna directivity pattern calculations.

Measurement of the field strength decrease with increasing distance of the receiver from the transmitter provides a convenient method of estimating ground conductivity (the greater the conductivity, the less rapid the signal decay with distance). The technique is to plot several data points at different distances on a graph of path loss values calculated for various ground constant combinations. One then does a best fit (curve matching) and assumes the ground constants are those of the calculated curve that provide the best fit to the measured data. To do a good job of matching, one needs data on relatively long radials (up to 25 or 50 miles preferred). The values obtained are thus the average values over a relatively large area. One problem with this technique is obtaining a homogeneous, relatively smooth area of sufficient extent for the average values obtained to be meaningful. This technique usually lends itself more to measurements at lower frequencies, where effects of ground irregularities tend to be less significant. One benefit of the technique is that the data obtained apply rather directly to radio propagation problems one might solve by use of ground constant information.

Maps of ground constants in Thailand are being prepared, where appropriate, to summarize the results of this measurement program, as part of a comprehensive report.

5. Subtask 5--Special Magnetic and Ionospheric Investigations

a. Faraday Rotation Satellite Reception

The MRDC Electronics Laboratory at Bangkok has recorded 54-Mc signals from satellite Transit-4A, 20- and 41-Mc signals from satellite Beacon-S66, and signals from satellite San Marco, 84A. The signal from Transit-4A is becoming weak, sporadic, and essentially unusable. Primary effort is of reception of S-66 on 20 and 41 Mc. Recording of San Marco, 84A, took place for about 10 days, in a joint Singapore/Bangkok long-distance satellite signal reception experiment. Satellite reception continues on a routine basis. Ionospheric electron density values are tabulated for each pass. Thus far, however, only data from Transit-4A have been analyzed.

When a linearly-polarized electromagnetic wave is propagated through an ionized medium (e.g., ionosphere) and is under the influence of the earth's magnetic field, the wave's resultant polarization vector is gradually rotated along a helical path. This phenomenon, commonly referred to as the Faraday rotation, is due to the property of the ionosphere which splits a radio wave into two characteristic modes. Each characteristic mode follows an independent path from satellite to receiver. The phase path lengths of these modes vary with time at a slightly different rate as the satellite moves, causing a rotation of the resultant polarization vector. The rate of rotation is approximately proportional to the columnar electron density between the satellite and observing station.

The Faraday rotation observed during the reception of radio signals from a satellite has been successfully used to study the composition and structure of the entire thickness of the ionosphere over a wide range of latitudes centered on Bangkok, particularly that part above the F-layer. Measurements by ionosondes from the earth's surface can be made only in the part of the ionosphere below the F-layer and only from the limited number of earth sounder locations. From the total number of Faraday rotations obtained from analysis of the recordings, one can determine the number of rotations due to the influence of the earth's ionosphere and magnetic field; and from this, determine electron content, equivalent slab thickness, and distribution of irregularities of the ionosphere near the equator. A knowledge of the columnar ionospheric electron density variation with time and latitude provides data on the validity of various theoretical models of the equatorial ionosphere. The satellite program also provides valuable data on the local ionosphere and the variation in density of the F-layer with latitude (trough effect).

Two methods of Faraday rotation analysis are used to determine ionospheric integrated columnar electron density. The simple method utilizes the rate of Faraday rotations to determine the localized content near a certain geographical region known as the transverse position. A more complex and complete method of analysis uses the actual number of rotations, measured from the transverse condition position, to determine electron density over a wide range of latitudes. Initial analysis efforts used the first method.

The more complete method was recently used in a joint Singapore/Bangkok/Hong Kong analysis. It is expected that this method will be applied to selected orbital passes common to all three stations to yield valuable density vs. latitude data.

The polarized rotation experienced by a linearly polarized wave, based upon simplifying assumptions is given by:[4]

$$\dot{R} = \dot{G}\int N dh, \tag{1}$$

where,

$\dot{R}$ is the rotation rate in rotations/minute

$\int Ndh$ is the effective electron content within a m^2 vertical column from the observer to the satellite

$\dot{G}$ is the coefficient of rotations/minute/$\int Ndh$

If $\dot{G}$ is known, we can calculate $\int Ndh$ from Eq. (1).

The values of $\dot{G}$ have been computer-calculated for the Bangkok region by the Department of Scientific and Industrial Research, Singapore.

The assumptions used in our analysis are discussed in detail in Ref. 4.

Figure 22 shows the variation in the angle of the satellite's transmission path with the geomagnetic intensity vector as the satellite makes its passage. The unique orbital position (transverse position, T_o) shown in the figure, occurs where the angle between the ray path and the earth's magnetic field is 90°.

Values of $\dot{G}$ are used for the rate method, while values of G are used in the rotation method. Values of G are computed by considering the effects of refraction on the ray path and by including a model of the earth's magnetic field in the computer program. Values of $\dot{G}$ are derived from the G values.

The variation of content with latitude will be determined in the future, using the more detailed method of analysis, for selected passes which allow data overlap between recordings from Bangkok, Singapore, and Hong Kong. This full method of analysis yields accurate results, and indicates the nature of large horizontal gradients which extend over many degrees of latitude.

Figure 23 shows a typical record of observations made by the MRDC Electronics Laboratory. The top channel shows the timing marks; the lower channel shows the linear display of the signal amplitude picked up by the dipole antenna. The spacing between nulls corresponds to a

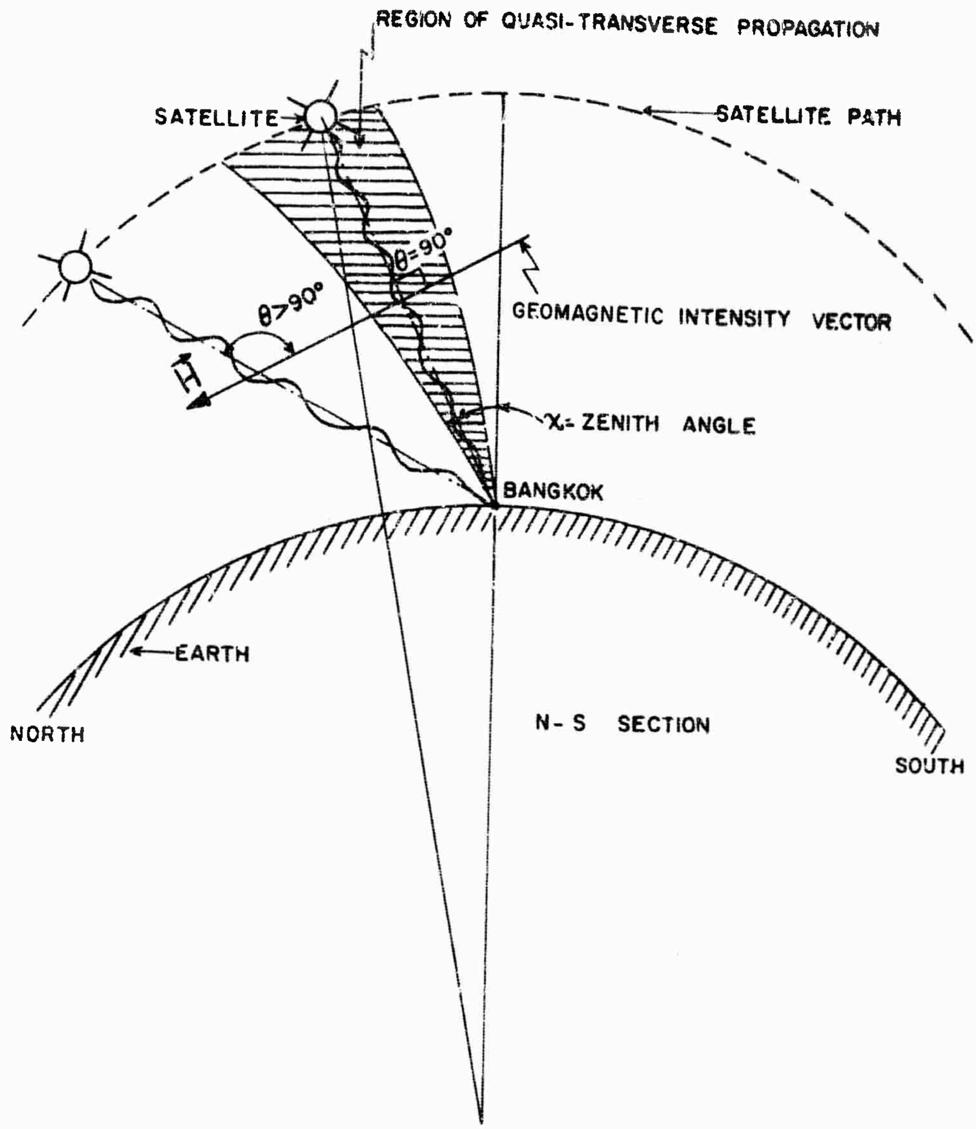

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FIG. 22 VARIATION IN ANGLE OF SATELLITE TRANSMISSION PATH

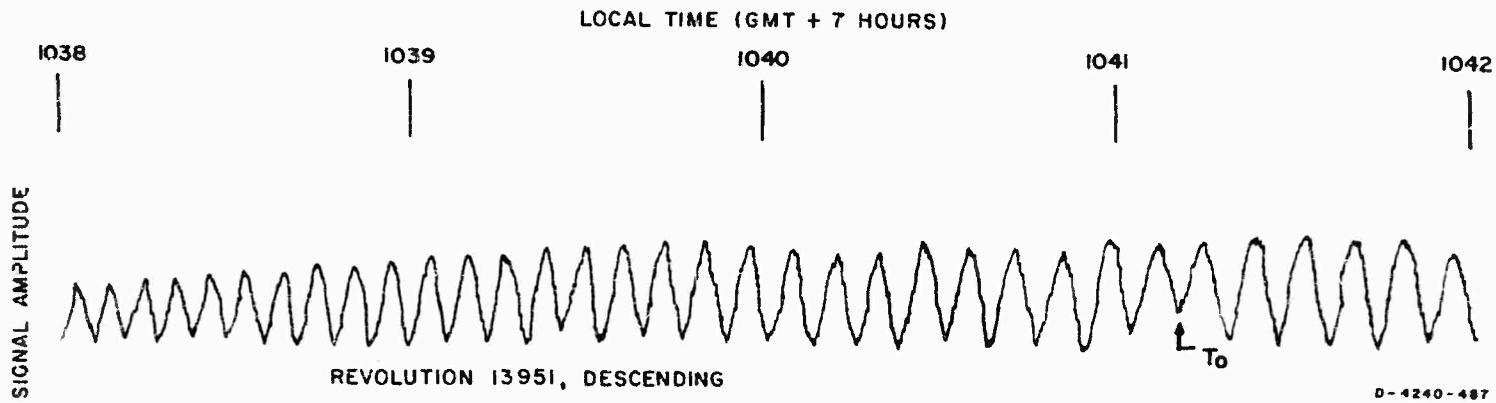

FIG. 23 FARADAY FADING RECORD, TRANSIT 4A (54 Mc)

rotation of the resultant wave polarization. For record analysis, an arbitrary zero was chosen at an amplitude minimum near the beginning of the continuous section of the fading record. Every other minimum was then numbered, because the spacing between the nulls corresponds to π radians, and two minima occur for each complete rotation of the plane of polarization. The rotation rate was calculated by averaging the number of rotations for 15-20 seconds, and was also plotted against time. A sample of the recording analysis is shown in Fig. 24.

The results of the analysis are given for the satellite's ascending and descending pass observation periods. The following results are deduced from about 170 satellite passages during March-October 1964. Figure 25 shows the electron content as a function of month and local time of each observation, and a smoothed curve has been drawn through the points to show the diurnal variation. The electron content during the daytime is about 20×10^{16} electrons/m^2, but during the night time it is very low--less than 5×10^{16} electrons/m^2.

Signals from three satellites are currently being received at the MRDC Electronics Laboratory, Bangkok: Omicron 1, S-66, and 1964-84A. Omicron 1 transmits on 54 Mc; S-66 transmits on 20.005, 40.010, and 41.010 Mc; and 1964-84A transmits on 20.005 Mc. These signals are received and the amplitude detected in order to record Faraday rotations.

The antennas used are horizontal dipoles. To minimize response to any vertically-polarized field component (mostly man-made noise and interference), a balanced 72-ohm-to-72-ohm transformer was installed at the antenna terminals to feed the coaxial transmission lines to the receivers.

The 54-Mc signal from Omicron 1 is weak, and to ensure reception, a low noise 54-Mc transistor pre-amplifier was designed and built.

Since the laboratory is located in a very high impulse noise area (C-2 sounder, ignition noise, etc.) an impulse noise blanker and detector was designed and built. This unit operates quite successfully.

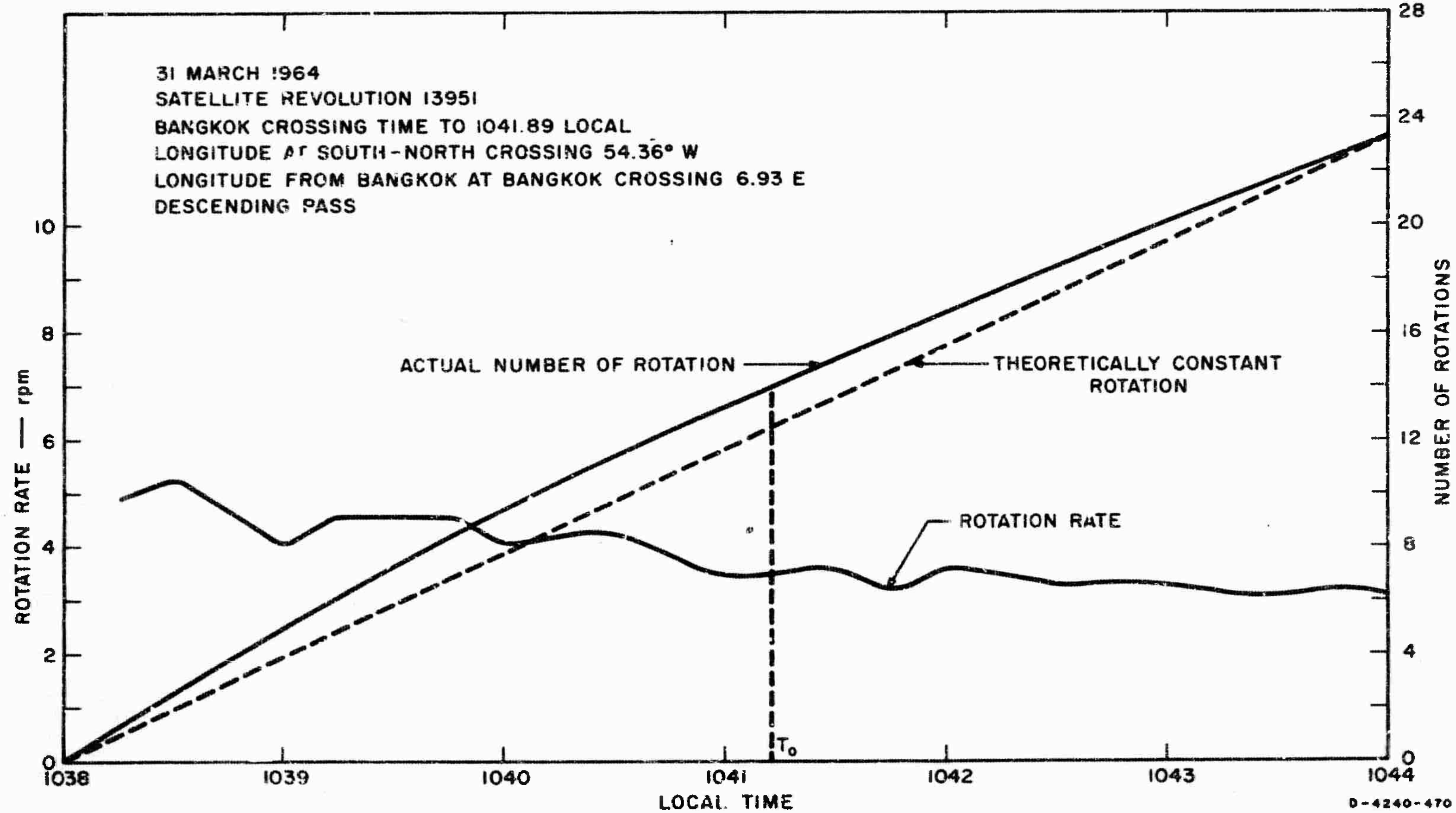

FIG. 24 SAMPLE RECORDING ANALYSIS

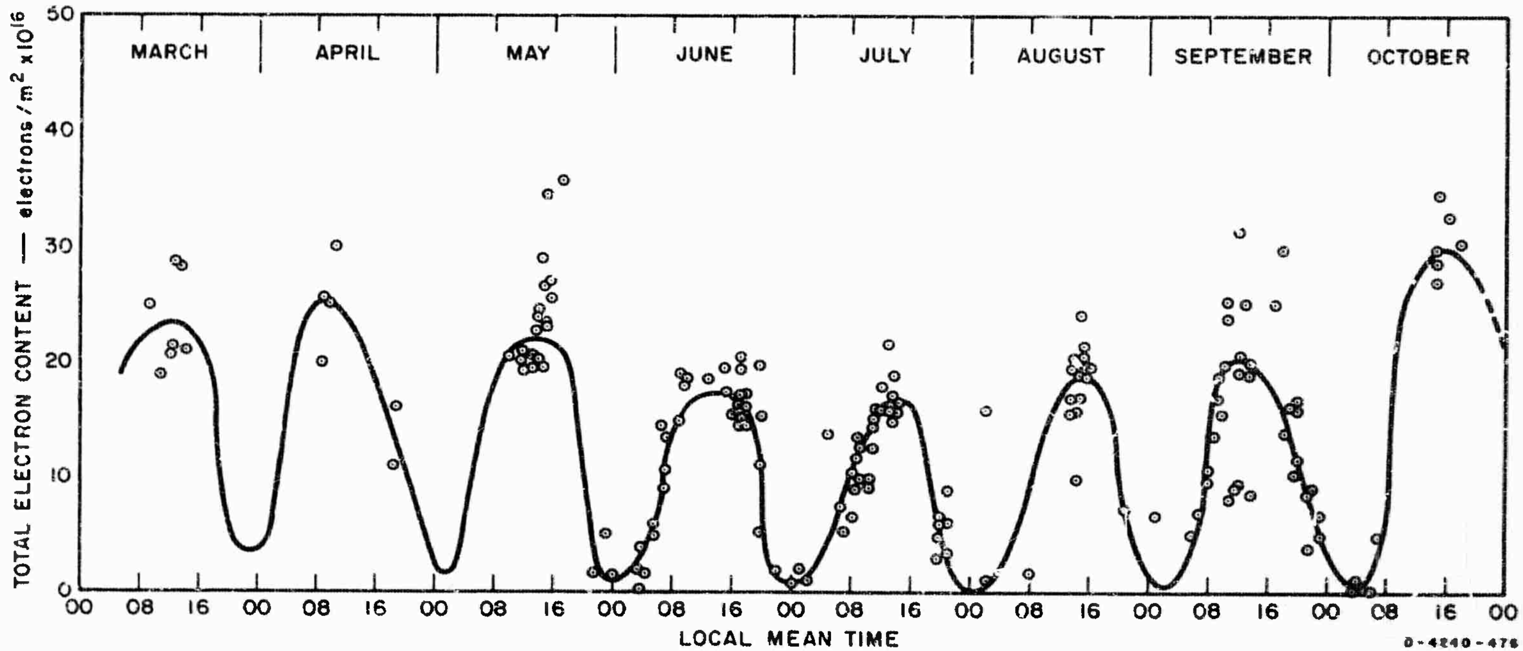

FIG. 25 HOURLY VARIATION OF ELECTRON CONTENT DEDUCED FROM FARADAY ROTATION OBSERVATIONS

Accurate one-minute time marks for the recorder marker pen are obtained from the frequency standard time divider through a one-shot multivibrator.

To record satellite passes occurring during nonworking hours, some means had to be found to turn the recorders on and off at precise times. It was decided that performing this twice automatically within a 16-hour period would suffice. Automatic digital time equipment was designed and constructed to automatically turn on the receiving and recording equipment when a satellite pass occurred.

A block diagram and a photograph of the satellite receiving system are shown in Figs. 26 and 27, respectively.

b. Magnetometer and Riometer

In the implementation plan for Subtask 5, a riometer and magnetometer are two additional pieces of equipment specified for studying the relationship between solar activity, and equatorial-area magnetic field, and ionospheric stability; and obtaining a measure of D-region absorption.

An antenna has been designed for use with the riometer.

References related to the selection and use of the magnetometer and riometer have been collected in preparation for their use. Contractual permission to obtain the equipment is expected early in the next reporting period.

6. Subtask 6--Ionospheric Factors Related to Local Frequency Prediction

a. Frequency Prediction Report Summary

Ionospheric data taken by U.S. Army Radio Propagation Agency (USARPA) personnel using a C-2 sounder in Bangkok, Thailand have been compiled there by Vichai T. Nimit and published by SRI as monthly bulletins, entitled "Ionospheric Data: Bangkok, Thailand," during September 1964-March 1965. These reports have been distributed to interested scientists and agencies, including International Geophysical Year (IGY) World Data Center A. Additional copies may be obtained from

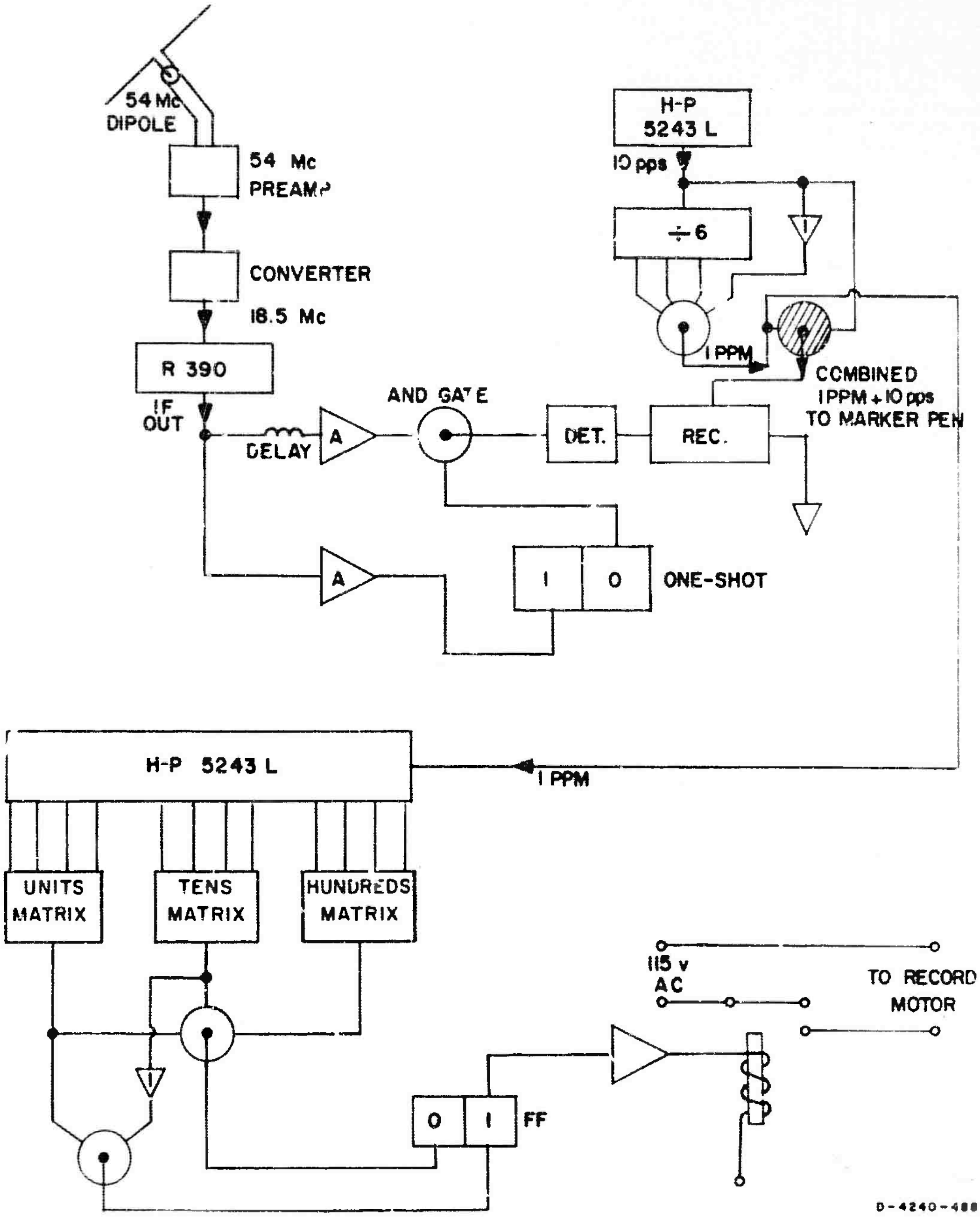

FIG. 26 SATELLITE RECEIVING SYSTEM, BLOCK DIAGRAM

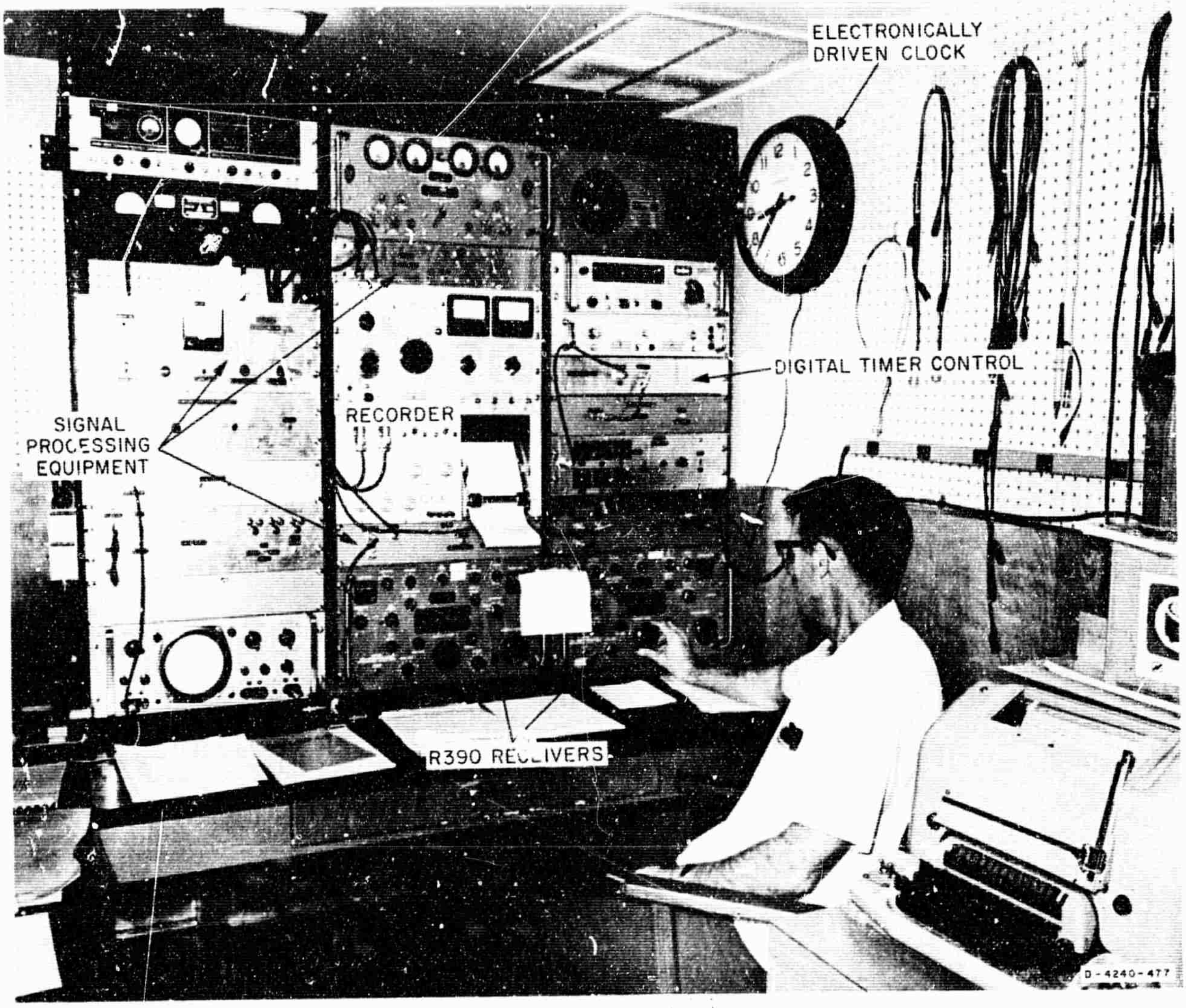

FIG. 27 SATELLITE RECEIVING EQUIPMENT

Stanford Research Institute, Menlo Park, California as available; also, a limited number of copies are available from IGY World Data Center A, Airglow and Ionosphere, CRPL, National Bureau of Standards, Boulder, Colorado (Attention: Mrs. Margo Lefton). Reports on subsequent months are in publication now and will be distributed as printed.

The data have been used to compare measured monthly median foF2 vs. local time with values predicted by methods employed by the National Bureau of Standards, Boulder Laboratories (NBS, numerical mapping), the USARPA (computer program input data, prepared by SRI),[5] and the National Physics Laboratory, New Delhi, India. Figure 28 shows an example f plot; the error curve indicates the difference between measured and predicted values. The three prediction techniques were rather comparable, when sampled over a year. There were often times-of-day during a given month when each would be best, and also month-to-month variation of relative prediction accuracy. However, on the average, either the NPL or NBS techniques appeared slightly better than the USARPA technique. This is to be expected since the USARPA technique is a longer-term technique, whereas the NPL and NBS methods require more recent input data. During 1964 (sunspot minimum), the NBS predictions seemed slightly better during summer, and the NPL predictions better during the winter. The average prediction error was about 1.5 Mc (too high), considering all three techniques. The error was smallest at sunrise and after sunset, and greatest at noon and midnight. Since the error trends are, on the average, of the same sign from month to month, the average prediction error could be reduced to ±1 Mc, using the measured data from the previous several months.* The error associated with the midday dip of foF2 observed by many workers[6,7] should be easier to correct than the midnight variation. The correction curve for 1965, suggested by Capt. Prapat Chandaket and derived by Rufenach and Hagn, is given in Fig. 29.

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* Ionospheric variations make it impractical to attempt predictions to closer than 0.5 to 1 Mc.

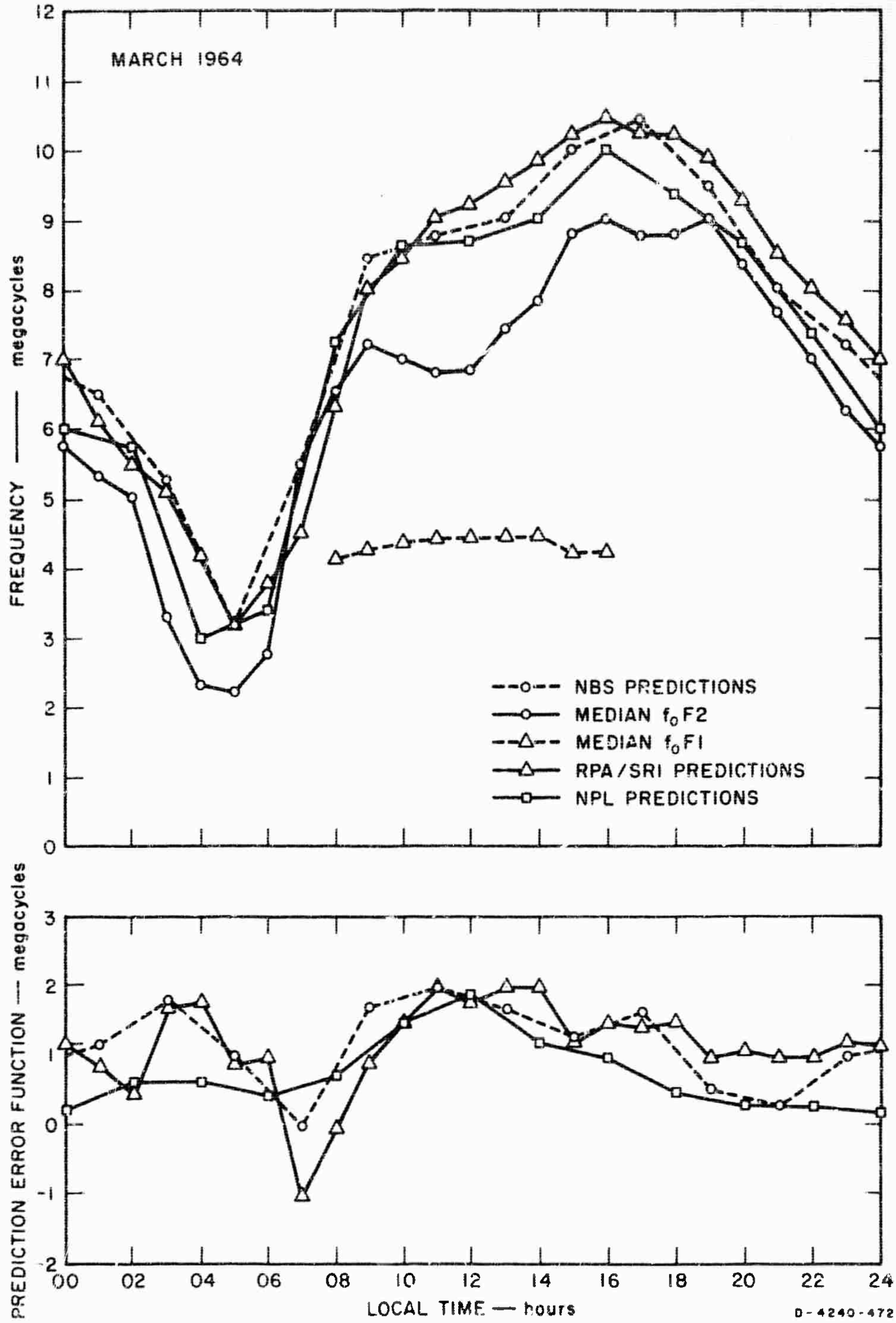


FIG. 28 COMPARISON BETWEEN PREDICTIONS AND MEASUREMENTS

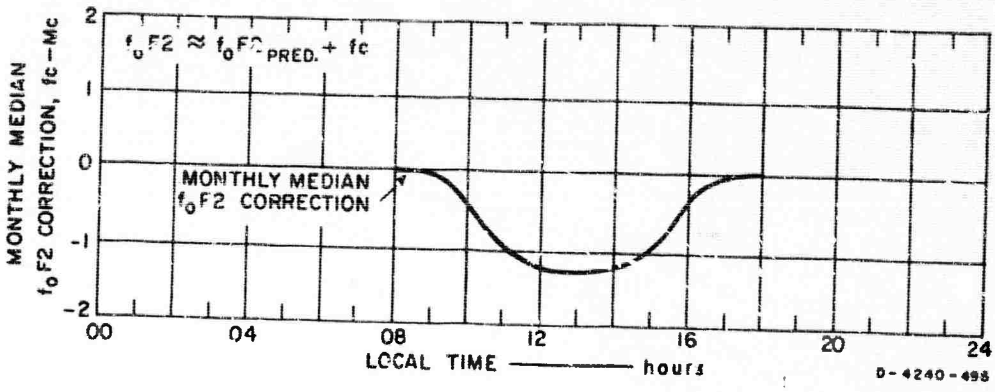


FIG. 29 MIDDAY DIP CORRECTION FOR MONTHLY MEDIAN f_oF2 PREDICTION — 1965

From the data analyzed through the reporting period, we may conclude that prediction of monthly median values of foF2 for Thailand during sunspot minimum can be accomplished well enough when C-2 sounder data are available to set the scale of the midday dip. The next phase of this work should be to study techniques to improve:

(a) Use of the sounder data to amend predictions (use the previous month's data or a running average of the preceding two or three months, etc.).

(b) Use of the C-2 data to make short-term (time scale of minutes or hours or days) predictions of foF2.

(c) Use of oblique incidence sounders in conjunction with the C-2 to define horizontal gradients in the ionosphere prevalent in the equatorial regions that would cause an error in the application of vertical incidence data to the prediction of propagation over oblique paths.

Height predictions for the F2 layer were also available from NBS and the USARPA/SRI computer program input data. Layer height,

h_L, is scaled as the smallest virtual height for the layer of interest and is an indicator of the true reflection height for the layer. This parameter is used in the USARPA/SRI computer program for ionospheric propagation on oblique paths.

The data indicate that prediction of monthly median values of h_L is slightly easier than prediction of foF2 (see Fig. 30, an excerpt from the October 1963 data summary, with the predicted h_L values added). Of the two techniques, the numerical mapping seemed the less accurate. The NBS technique predicted too high by about 15 percent during the day, whereas the USARPA/SRI predictions were about 8 percent low for that time of day. However, the observed daily variation from monthly median predicted values was often 50 percent or more for both techniques. The standard deviation of daily observed differences from monthly predicted values was least during early afternoon and evening.

Fortunately, predictions of MUF for short paths (less than 200 km) are relatively insensitive to errors in h_L. For example, on the 66-km path between Bangkok and Ayutthaya, a 100 percent error in h_L (150 to 300 km) would cause only about a 2 percent error in predicted MUF; and on a 166-km path between Ayutthaya and Nakon Sawan, the same height error produces only a 7 percent error in predicted MUF. For greater path lengths, the error increases rapidly.

During the reporting period, work was begun by Mr. Clifford Rufenach to predict the occurrence of sporadic E and spread F over Bangkok, using the C-2 sounder data base. The approach is to predict the probability of occurrence at a given hour, based upon the history of previous occurrences, including conditional probabilities (e.g., probability of occurrence at an hour of interest, given that it was or was not present during the preceding hour, etc.). Preliminary results of this effort are given as Table I.

b. Use of Oblique Sounders to Investigate Short Paths

Tropical forests severely attenuate HF and VHF ground waves. In the HF case, the skywave signals override groundwave signals

IONOSPHERIC DATA
MONTHLY MEDIAN CHARACTERISTICS
BANGKOK, THAILAND
OCTOBER 1963

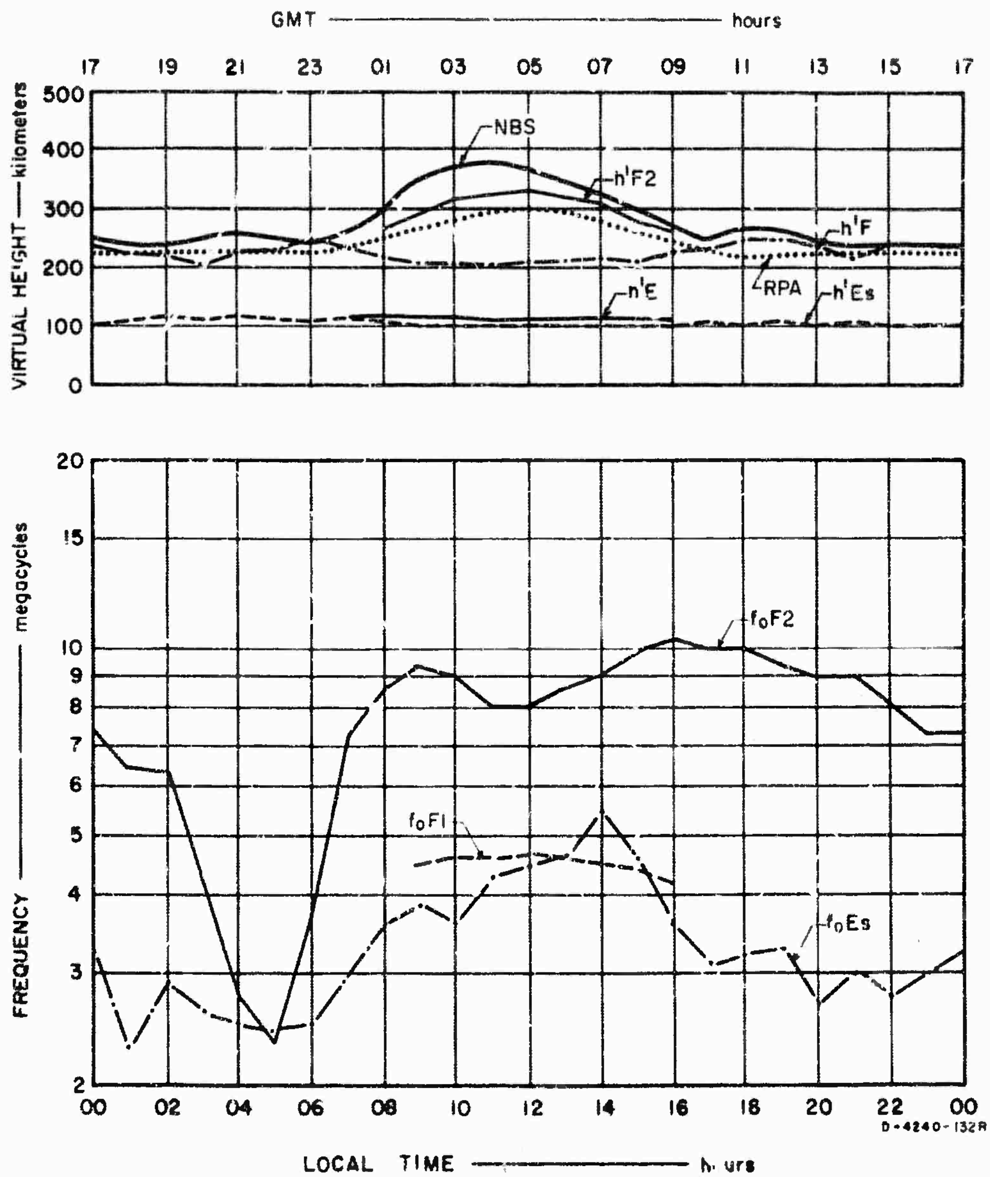


FIG. 30 IONOSPHERIC SUMMARY GRAPHS

Table I

LONG TERM IONOSPHERIC PHENOMENA

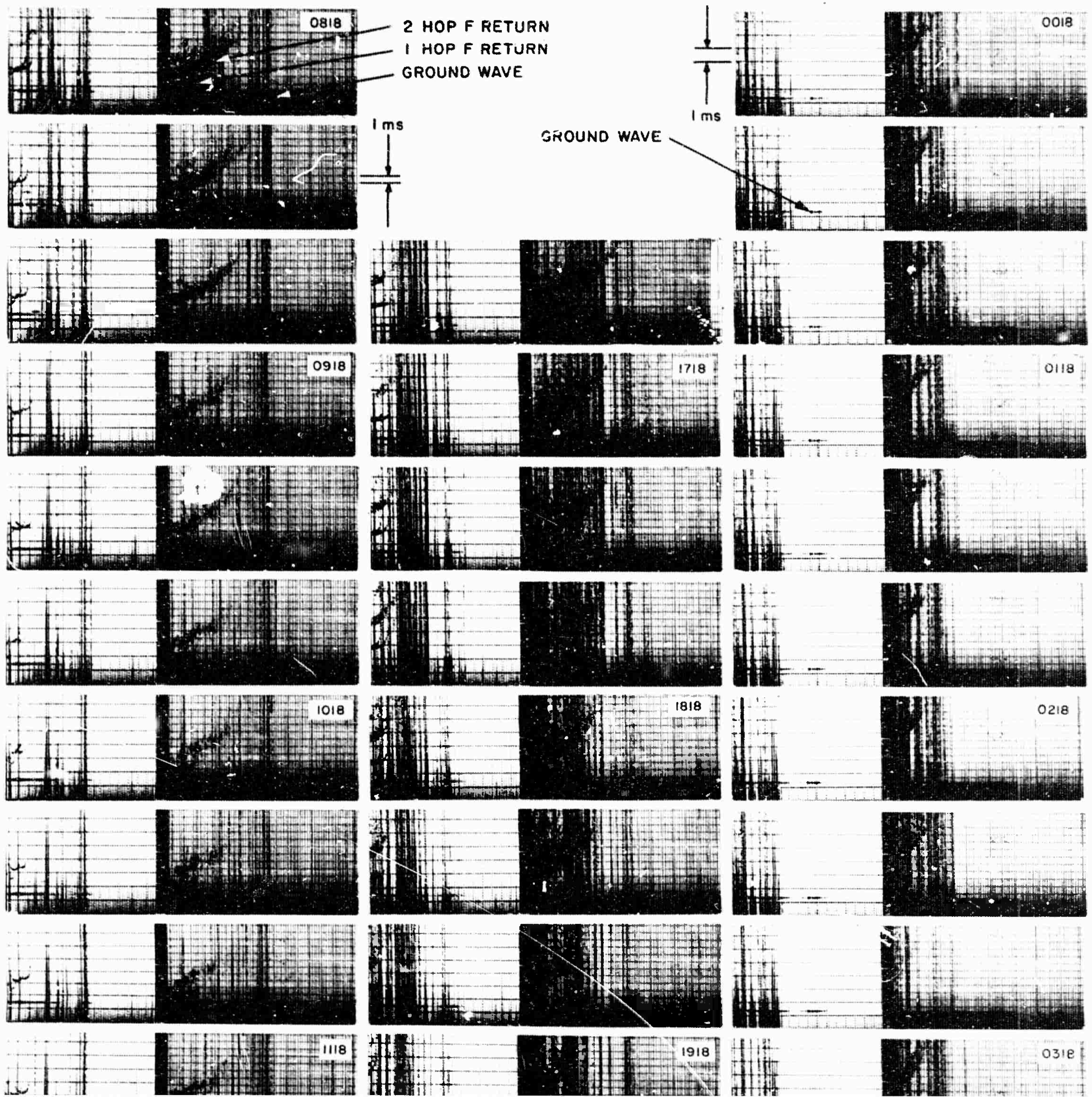
(observed on C-2 vertical incident sounder, Bangkok, Thailand)

Month/Year	Hours Possible	Hours Observed		
		Blackout	Spread F	Sporadic E
September 1963	604	16	1	333
October 1963	717	7	7	218
November 1963	613	3	5	230
December 1963	719	1	17	305
January 1964	714	10	23	323
February 1964	677	2	44	352
March 1964	741	10	58	275
April 1964	603	9	27	313
May 1964	656	23	40	424
June 1964	662	31	47	427
July 1964	508	45	37	376
August 1964	692	44	40	468
September 1964	566	16	19	354
October 1964	318	23	2	131
November 1964	611	21	5	194
December 1964	548	66	1	119
January 1965	526	50	--	313
February 1965	531	41	23	205
March 1965	422	4	35	213

at distances exceeding a few miles. For some intermediate distance, both the skywave and the groundwave will be received Oblique sounders can be used to directly measure the relative magnitude of each component of the received signal. The ability of the sounders to scan over the entire HF frequency spectrum and lower end of the VHF band enables one to examine a variety of cases pertinent to man-pack and field radios. The effect of various types of antennas on received signal strength can be investigated by using selected combinations of antenna types on successive frequency scans.

The convenient physical arrangement and location of oblique sounders, required to accomplish work under another contract [DA-28-043 AMC-00082(E)], where investigations were conducted into the dependence of ionograms upon receiver sounder spacing on a long-range propagation path, provided a convenient test of ability of the sounders to investigate short paths. The sequence of ionograms shown in Figs. 31 and 32 were selected to illustrate one type of sounder output. The path from Mountain View to Sonoma, California (Fig. 31) is largely over San Francisco Bay, while the longer path from Mountain View to Middletown (Fig. 32) is rather evenly divided between San Francisco Bay and land. The transmitter power was 30 kw, with a pulse length of 1 msec. The antennas were horizontal log-periodic types pointed approximately 90 deg from the paths shown. The transmitter power was much higher than possible with man-pack radios, and the antennas considerably different and elevated to a height of 80 feet. The test conducted more closely matches the case of two truck-transportable field radios such as the AN/GRC-26.

The Mountain View-to-Sonoma path (Fig. 31) clearly shows groundwave on the lower part of the spectrum. A competing skywave is also clearly shown which varies in maximum observed frequency (MOF) and lowest observed frequency (LOF) as the ionosphere changes. Ionospherically-propagated ground backscatter which extends the 2F MOF above the normal MUF is also shown on many of the daytime ionograms. The backscatter is much weaker than the normal one-hop ionospheric path.



0818
2 HOP F RETURN
1 HOP F RETURN
GROUND WAVE
1 ms
GROUND WAVE
1 ms
0018
0918
1718
0118
1018
1818
0218
1118
1918
0318

2

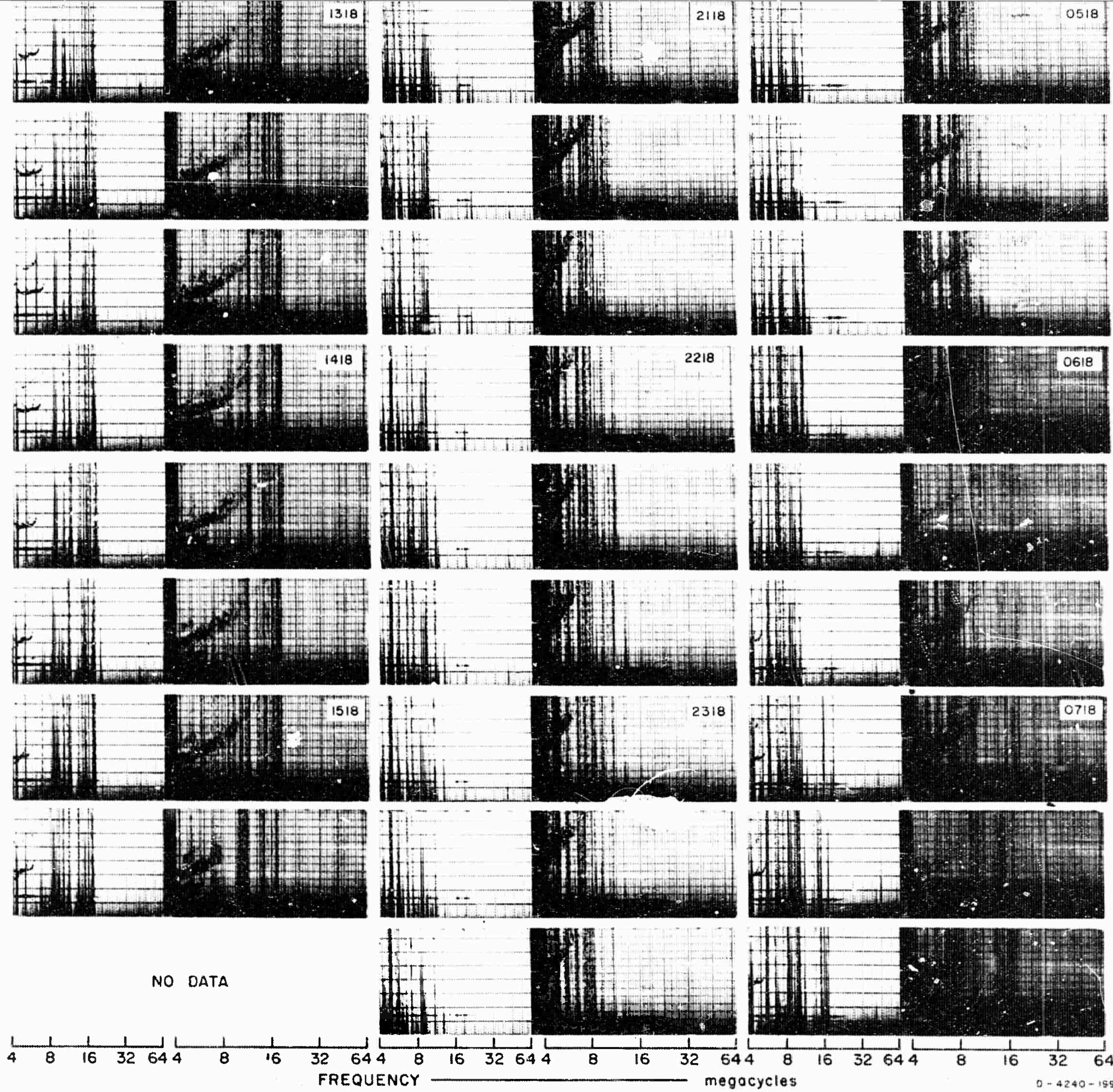
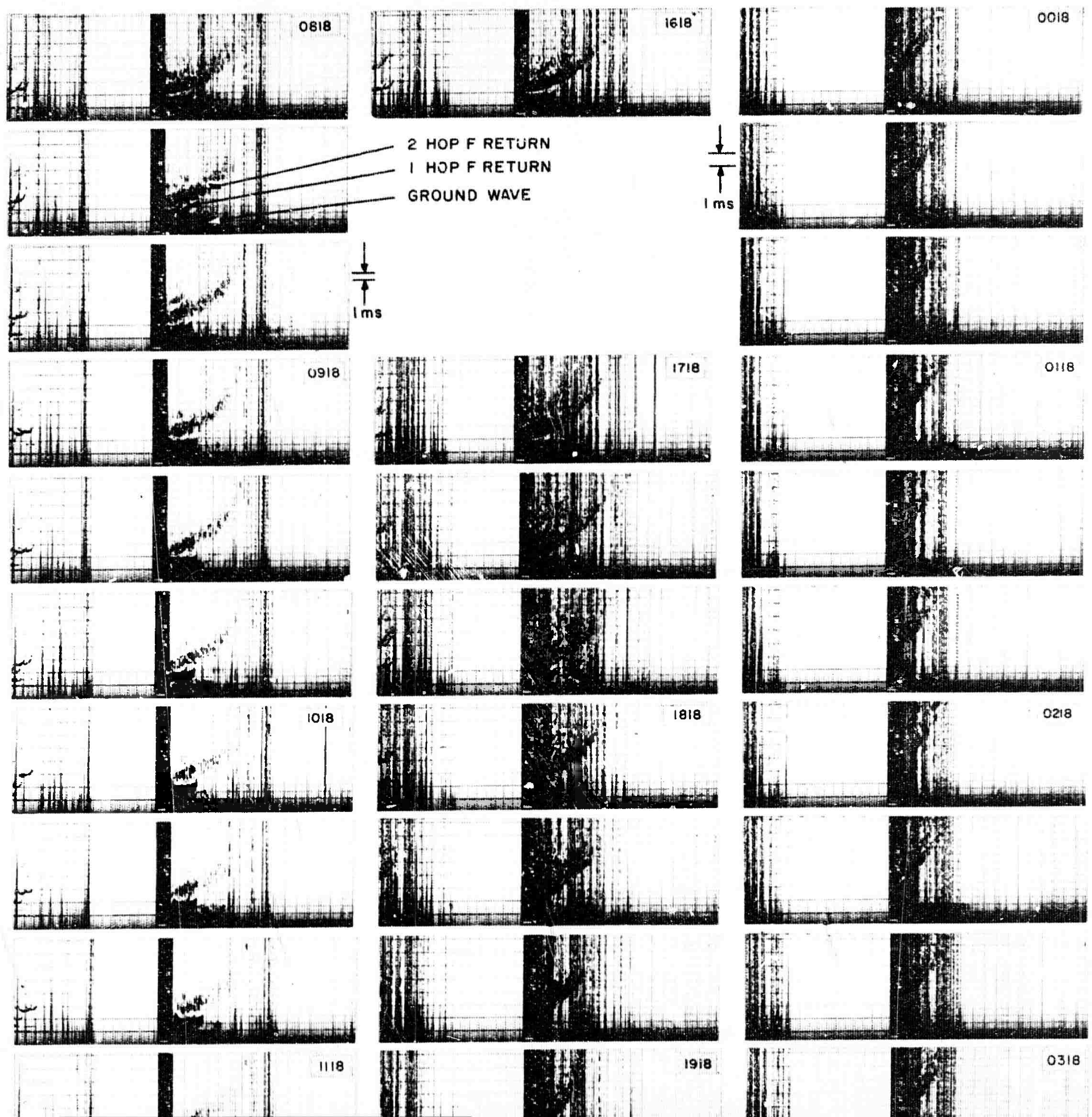
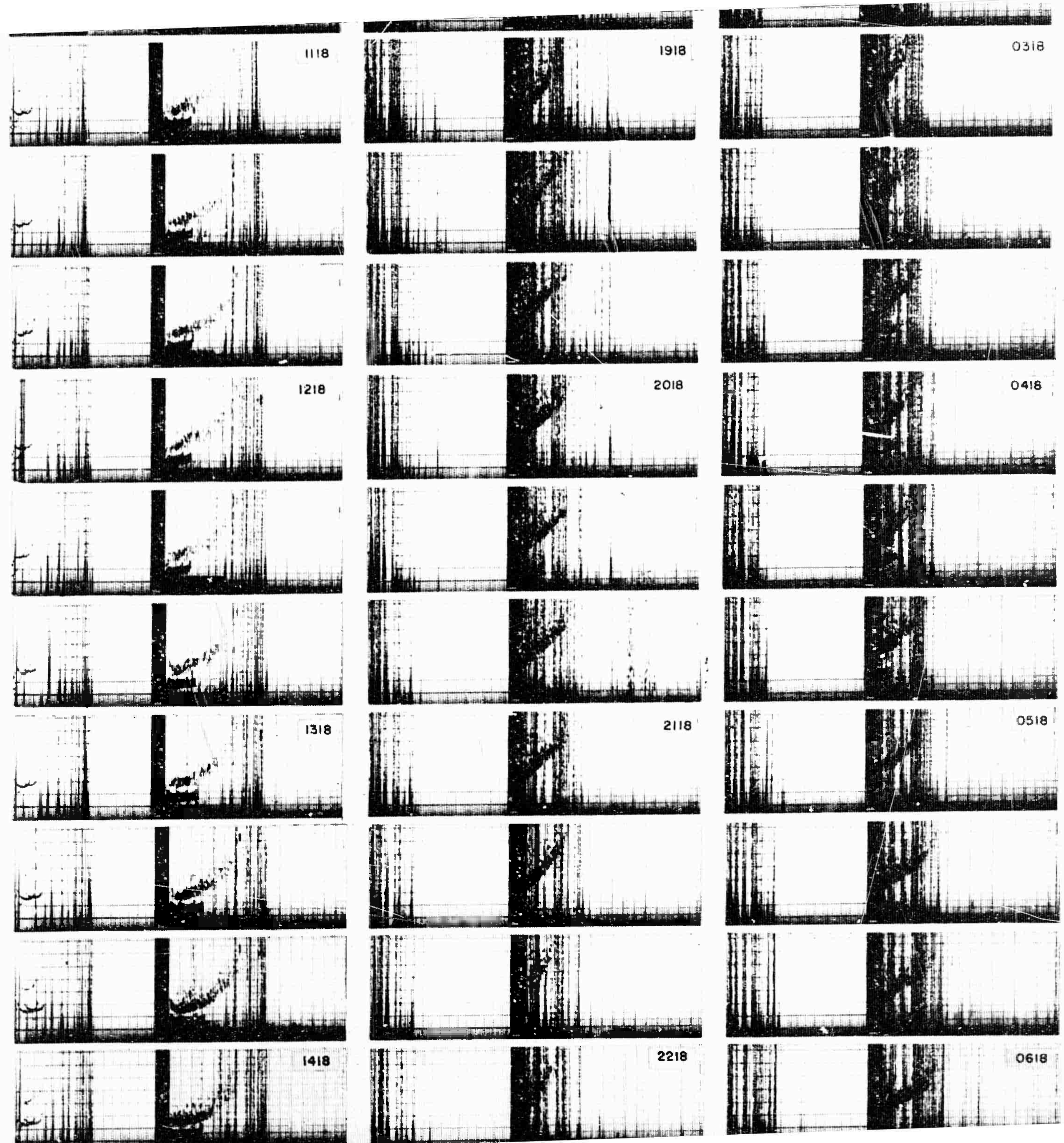


FIG. 31 MOUNTAIN VIEW/SONOMA SHORT-PATH OBLIQUE IONOGRAMS


0818
1618
0018
2 HOP F RETURN
1 HOP F RETURN
GROUND WAVE
1 ms
1 ms
0918
1718
0118
1018
1818
0218
1118
1918
0318



2

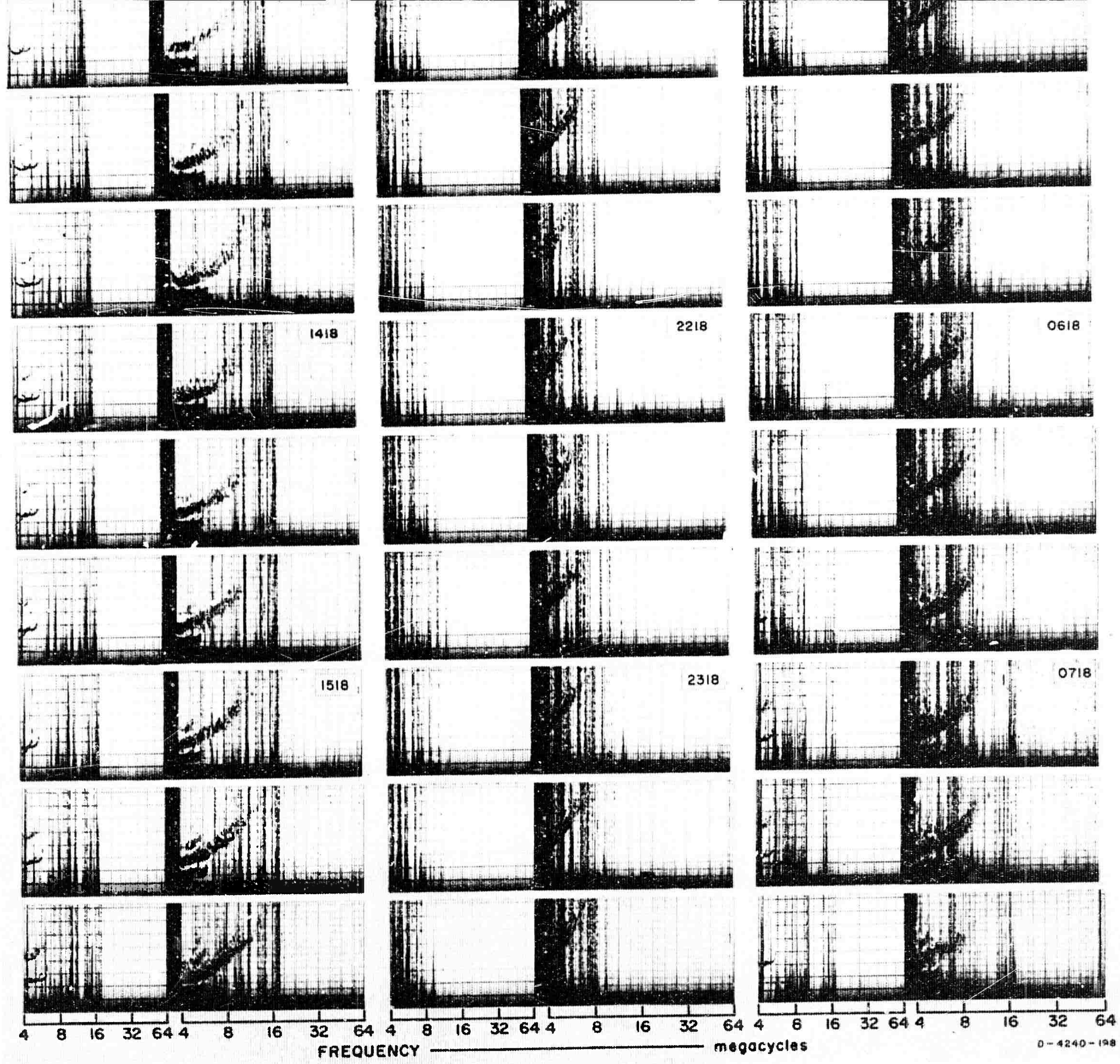


FIG. 32 MOUNTAIN VIEW/MIDDLETOWN SHORT-PATH OBLIQUE IONOGRAMS

3

The groundwave observed on the Mountain View-to-Sonoma path is certainly enhanced by the salt-water path over San Francisco Bay. The high antennas also result in stronger groundwave signals than would be expected from low field antennas. Also, noise levels were lower than one would expect in the tropics. Thus, caution is urged in using or extrapolating this selected example to an operational context in Thailand.

Weak groundwave signals can be observed on the Mountain View-to-Middletown path, and the maximum frequency of the signal is lower than observed on the shorter path. When using oblique sounders over a 6-km path from Menlo Park to Mountain View, using tactical antennas and transmitter powers equivalent to man-pack levels, no groundwave was observed. The only observable signal was identified as a one-hop F-layer skywave.

Two oblique-incidence sounders procured by USARPA were loaned to the project to further investigate short paths under a wide variety of conditions. These two sounders, Granger Associates Model 1907, are mounted in S-141-type shelters, mounted on rubber-tired wheels. The mobile units are designed to maximize portability, minimize set-up time, and be rugged enough for field use.

The USARPA sounders have completed initial checks and have been placed in operation on an all-land 100-km path between Camp Hunter Liggett and Hollister, California. Several types of field antennas, including slant wire, inverted-L, dipole, and whips, have been installed. The sounder transmitter output power and receiver bandwidth have been adjusted to simulate the performance of field radios.

Initial trials have shown that the sounders can operate into the high standing-wave levels of narrow-band field antennas as long as output power levels are reduced. Sufficient data have not yet been accumulated to permit a complete analysis of the ability of the sounder to explore the propagation paths of HF man-pack and field radios, but initial trials are quite encouraging. No groundwave signals were observed at the highest sounder power levels (30 kw peak pulse power) using any of the antennas (slant wire, whip, log periodic, dipole, inverted-L).

The signal from a pair of slant wire antennas has been shown to be about 20 db lower than that from a pair of half-wave dipoles placed a quarter-wave above ground. The signal-to-noise ratio difference during daytime is even greater than 20 db.

7. Subtask 7--Effects of Tropical Environment on Antenna Performance

a. General Comments

Tropical forest areas can effectively modify the radiation patterns of field antennas installed in the forest. The effect on the pattern is complex and inadequate data are available to accura ly model or compute pattern alterations. Consequently, a series of full-scale measurements have been initiated.[8] Precise knowledge of the radiation patterns of selected field antennas when used over flat terrain and in selected forest areas are being determined. The Xeledop antenna pattern measuring equipment is being used.[9] The Xeledop efforts are discussed in Paragraphs b, c, and d following:

Non-Xeledop measurements on whip and dipole antennas were performed in Thailand, giving results on gain vs. height, forest polarization effects, and antenna impedance in proximity to trees. These measurements are discussed in Paragraphs e and f.

b. Flat Terrain Measurements

The antennas, their heights, and measurement frequencies are listed in Table II. They were installed over a flat, disked wheat field near Lodi, California and Xeledop measurements made to determine their actual normal patterns.

The antennas were spaced sufficiently far apart to effectively eliminate mutual coupling effects. No metallic objects other than feed lines were permitted near the antennas. The terrain was flat for several miles around. Special care was taken to calibrate all measurement gear and to carefully record all antenna dimensions and physical characteristics so that measurements over flat terrain could be compared

Table II

TACTICAL ANTENNAS TESTED BY XELEDOP METHOD, LODI, CALIFORNIA

Type	Length, feet	Height, feet	Measurement Frequency, Mc	Polarization of Measurement
Monopole	-	15.6	2.0	Vertical
Monopole	-	15.6	4.0	Vertical
Monopole	-	15.6	5.0	Vertical
Monopole	-	15.6	6.0	Vertical
Monopole	-	15.6	8.0	Vertical
Monopole	-	15.6	15.0	Vertical
Balanced dipole	31.2	16.4	4.0	Horizontal
Balanced dipole	31.2	16.4	5.0	Horizontal
Balanced dipole	31.2	16.4	6.0	Horizontal
Balanced dipole	31.2	16.4	8.0	Horizontal
Balanced dipole	31.2	16.4	10.0	Horizontal
Balanced dipole	31.2	16.4	15.0	Horizontal
Unbalanced dipole	58.4	23.0	2.67	Vertical, horizontal
Unbalanced dipole	58.4	23.0	5.0	Vertical, horizontal
Unbalanced dipole	58.4	23.0	8.0	Vertical, horizontal
Unbalanced dipole	58.4	23.0	15.0	Vertical, horizontal
Unbalanced dipole	77.8	2.0	2.0	Vertical
Unbalanced dipole	77.8	2.0	4.0	Vertical
Unbalanced dipole	77.8	2.0	6.0	Vertical, horizontal
Unbalanced dipole	77.8	2.0	10.0	Vertical, horizontal
30° slant wire	58.4	-	2.0	Vertical
30° slant wire	58.4	-	4.0	Vertical, horizontal
30° slant wire	58.4	-	6.0	Vertical, horizontal
60° slant wire	46.7	-	5.0	Vertical, horizontal
60° slant wire	46.7	-	15.0	Vertical, horizontal
2:1 inverted-L	58.4	29.2	2.67	Vertical, horizontal
2:1 inverted-L	58.4	29.2	8.0	Vertical, horizontal
5:1 inverted-L	58.4	11.7	10.0	Vertical, horizontal

with an identical antenna in forest areas or other environment. Several reference antennas of standard types were measured simultaneously with antennas under test so that some estimates of gain and radiation efficiency of the test antennas could be made. Some of the setups will be repeated using the Granger sounders and employing an ionospheric reflection for an additional comparison and check.

Figures 33 and 34, respectively, show the horizontal and vertical polarized* measured patterns of a 8-Mc dipole antenna elevated 23 feet above the ground. The horizontal pattern (Fig. 33) shows the expected lobes off each side of the antennas and a slight drop in response as very high angles are reached. Figure 34 (vertical pattern) shows well-formed lobes off each end of the antenna at 40° to 50° in elevation. The 3-db contour of the vertical pattern is less than 1 db in magnitude from the 3-db contour of the horizontal pattern.

The data from all types of antennas measured have been processed and plotted like the examples shown in Figs. 33 and 34. Final analysis of the data is underway and will be reported in the next period. A site has been selected in a forest area west of Lake Almanor in northern California for initial forest measurements. Plans for moving the equipment into this area have been completed and measurements planned during late April and May of 1965.

c. Thailand Xeledop Measurements

Planning discussions have been held between representatives of USAEL, Jansky and Bailey, and Stanford Research Institute on the measurement of J & B antennas and the Institute tactical antenna selection in Thailand. Tentative plans have been made to measure antennas in Thailand during the next dry season.

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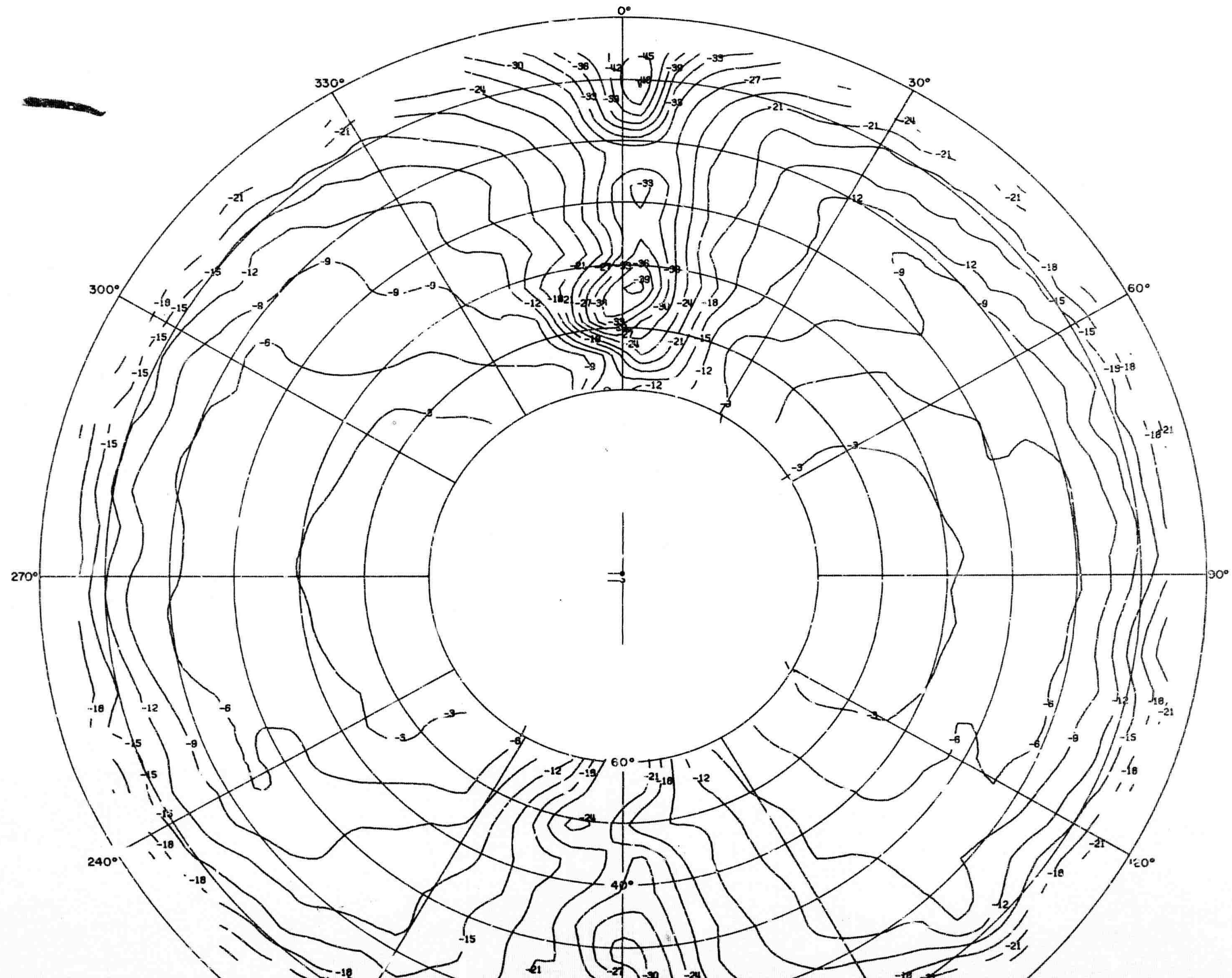
* Ref. 9 contains a description of the reference axis used and a precise definition of the polarization vector.



0°
30°
60°
90°
120°
240°
270°
300°
330°
60°
40°

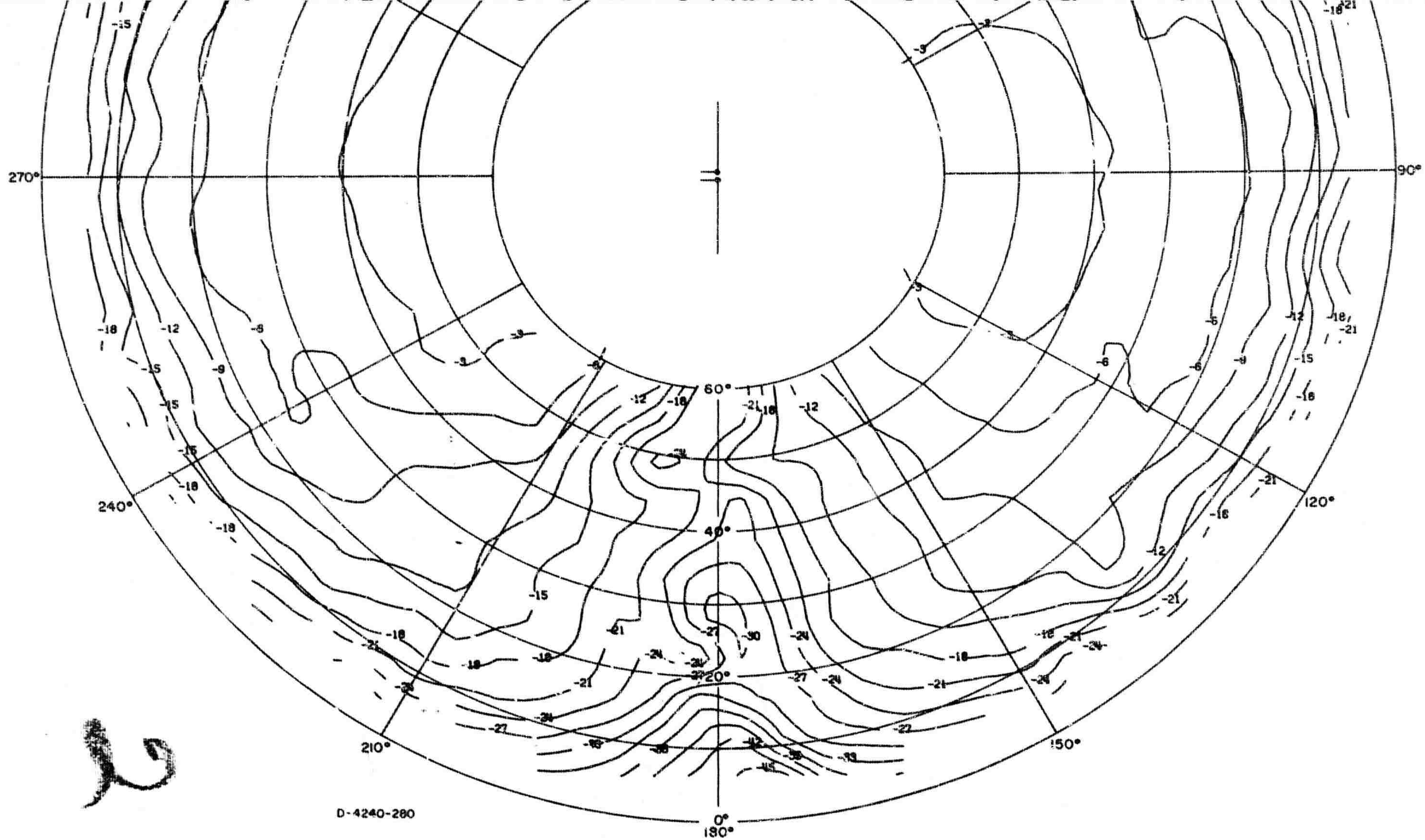
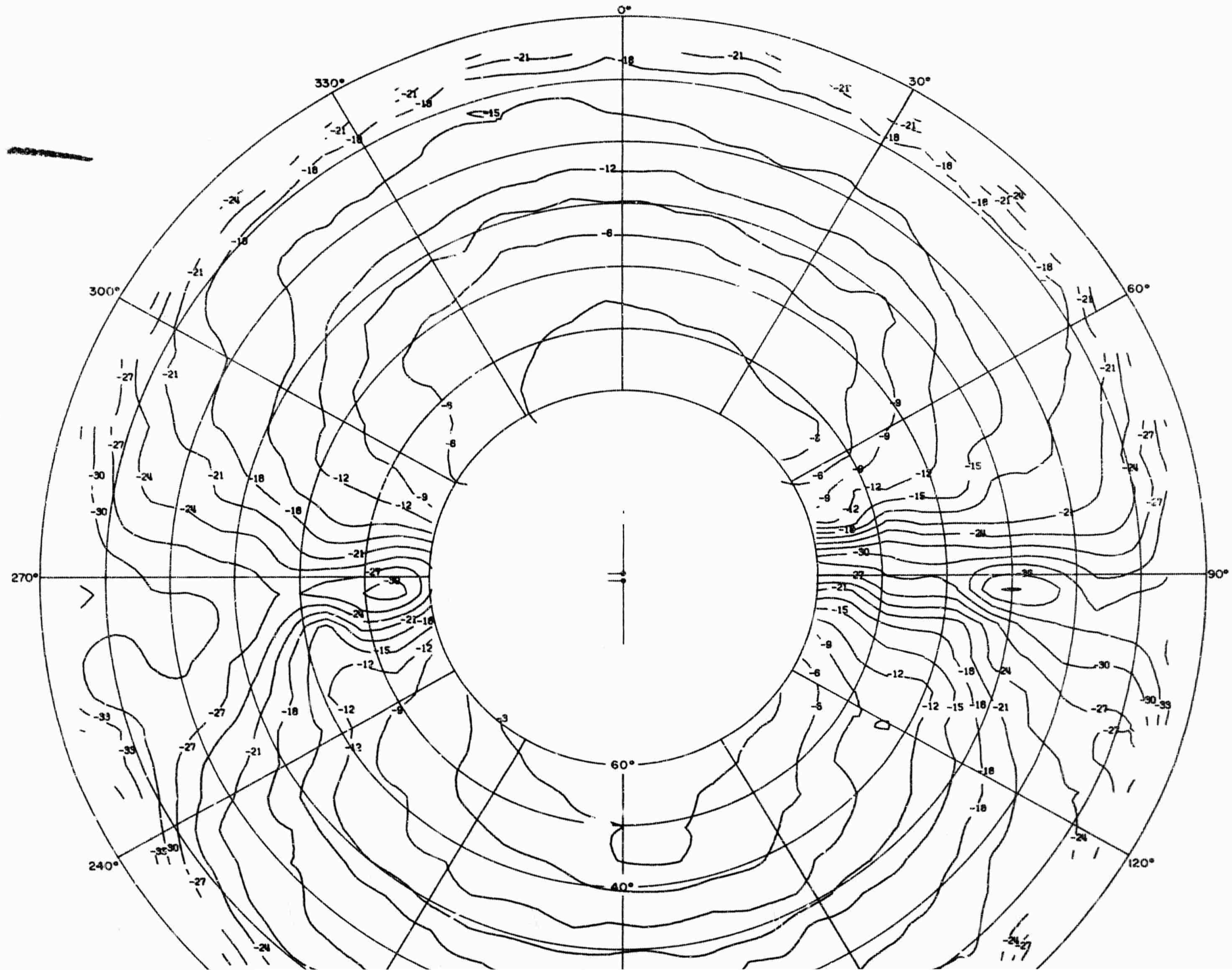
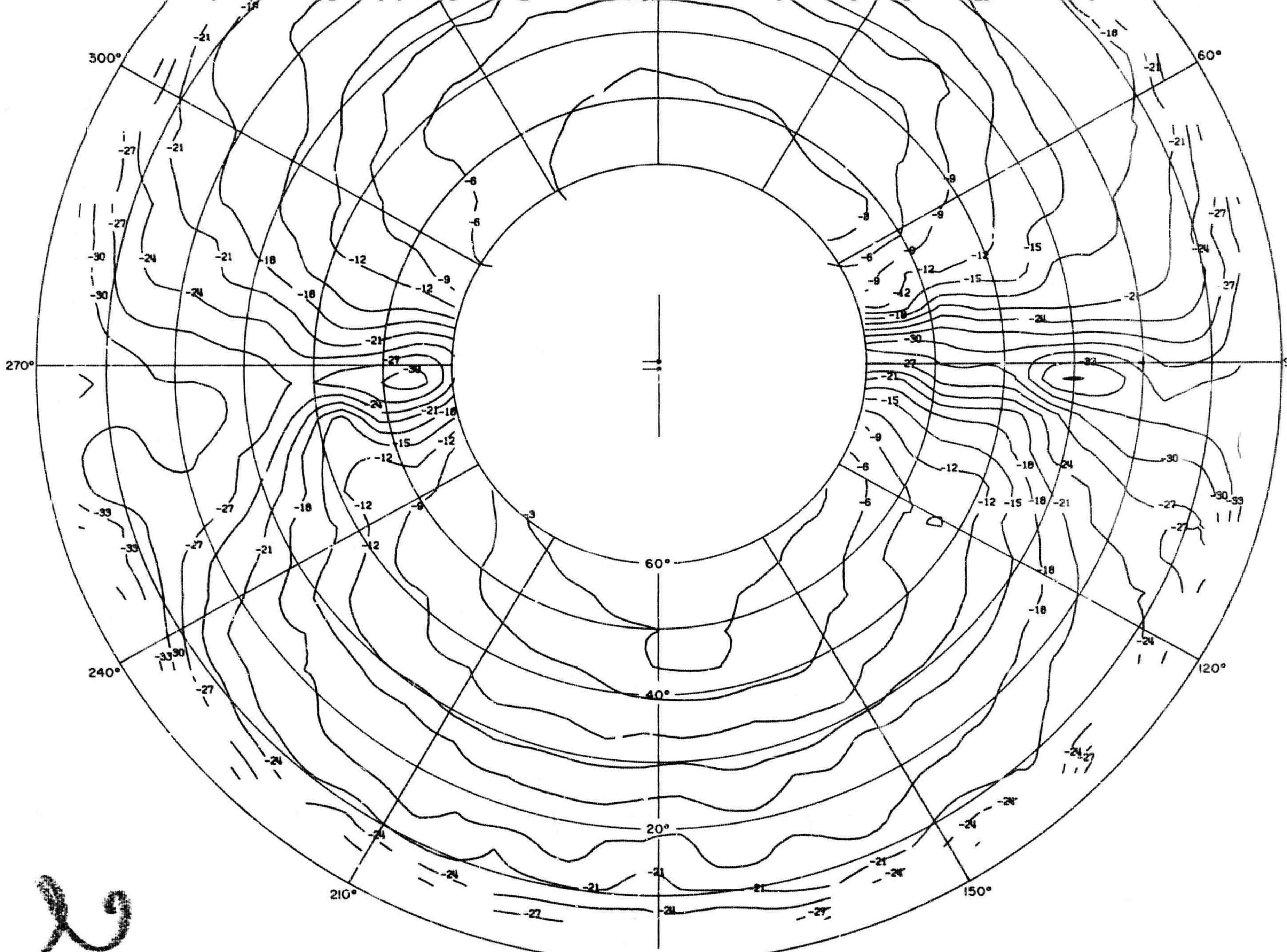


FIG. 33 CONTOUR PLOT OF 8 Mc DIPOLE ANTENNA (λ/2) PATTERN (Horizontal Polarization)



0°
30°
60°
90°
120°
240°
270°
300°
330°
60°
40°



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D-4240-258

FIG. 34 CONTOUR PLOT OF 8 Mc DIPOLE ANTENNA (λ/2) PATTERN (Vertical Polarization)

d. VHF Xeledop

The HF Xeledop has been successfully used at frequencies as high as 30 Mc, and could be modified to work up to 50 Mc. To maintain a versatile antenna measurement capability, the Institute has developed a VHF Xeledop capable of operation over the 50-120-Mc frequency range. Overall and internal views of the unit are shown in Figs. 35 and 36.

The VHF Xeledop will be used to explore pattern deformations of VHF antennas in tropical forest areas. Operating procedures will be similar to those used with the HF model.

e Some Field Strength and Antenna Impedance Measurements in a Tropical Forest

VHF propagation in tropical forests is affected by several factors, among which could possibly be: change in wave polarization and other scattering effects or antenna impedance change due to proximity to foliage.

A field trip to the forest near Rayong was undertaken to make a brief examination of this problem. Various combinations of transmitter and receiver sites were used; in fields, along forest trails, and in dense forest growth. Antenna polarization angles were varied to detect signal strength variations due to the polarization factor.

A second type of measurement was made to determine the effect upon the antenna impedance as an antenna was moved with respect to a large tree in an open area.

A series of back-pack tests were conducted to evaluate wave scattering effects.

The consequences of using balanced and unbalanced dipoles were investigated.

A number of preliminary conclusions resulted:

(1) Dry brush or leaves touching the antennas did not produce noticeable changes in field strength.

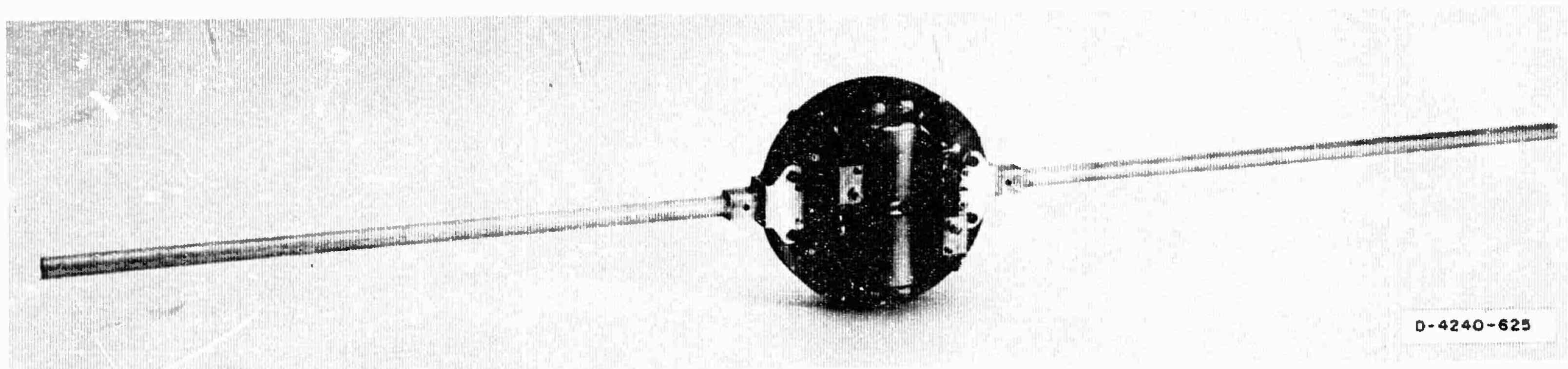

FIG. 35 VHF XELEDOP, OVERALL VIEW

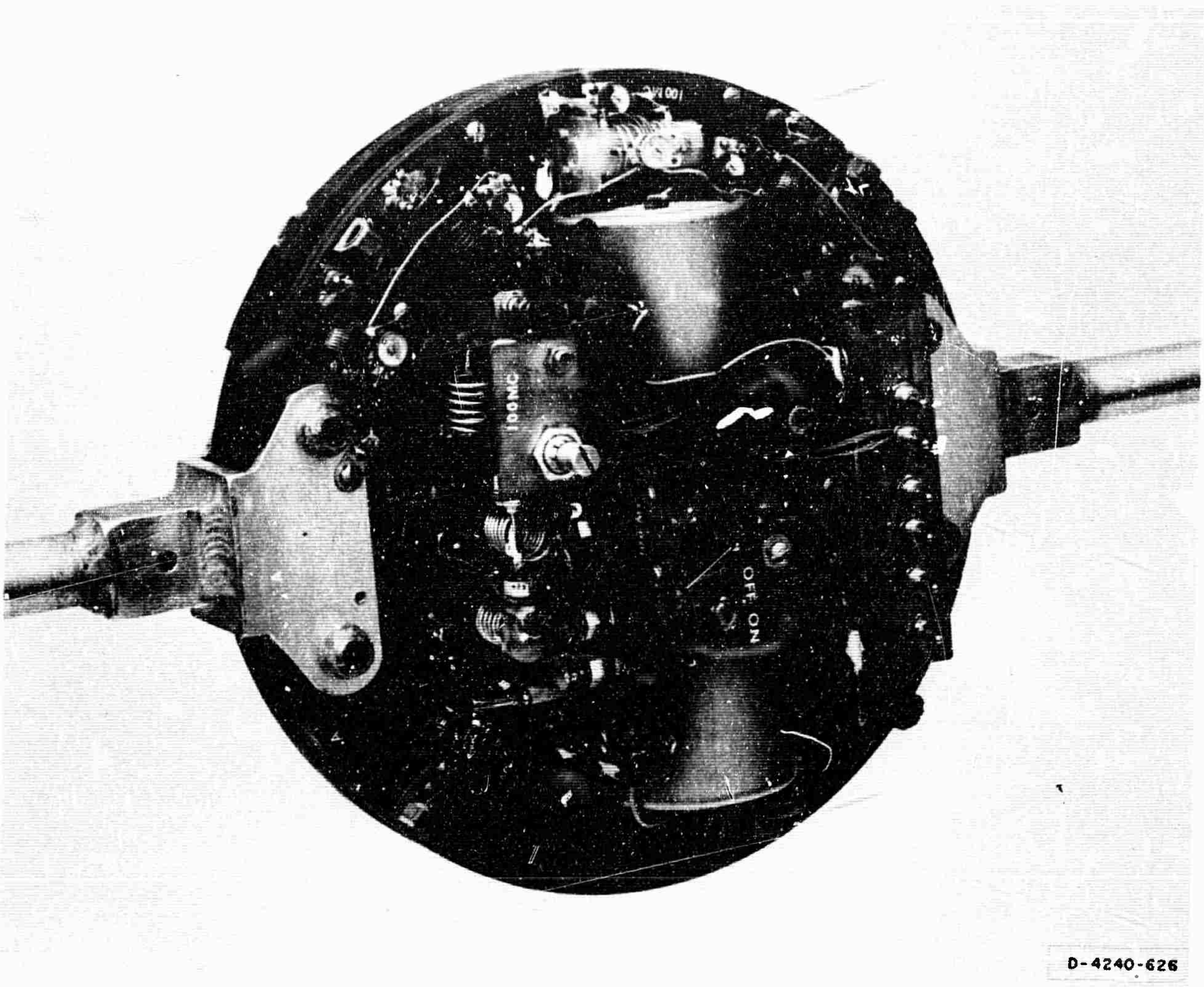

FIG. 36 VHF XELEDOP, INTERNAL VIEW

(2) Polarization tests showed that for a vertical transmitting antenna in the forest, signals received in an open field were maximum vertically and minimum horizontally, but that the received signal within the forest would have changes in polarization due to reflections from nearby foliage.

(3) Antenna input impedance changes due to foliage were small for a tuned dipole.

(4) It appears that scattering is the main forest factor causing degradation of communication performance.

(5) Detector readings fluctuated greatly for small antenna movements. It was important to move about to obtain maximum readings.

(6) The balanced dipole appeared superior to the unbalanced dipole because it was less affected by its environment, gave higher signal strength values, and it did not matter which end was up.

f. Antenna Elevation Effects

During early 1965, some antenna elevation effect measurements were conducted in Thailand in flat, open terrain. These measurements were made to compare the results of independently elevating the receiving and transmitting antennas, and to compare the results of an elevated 10-foot whip antenna with an elevated half-wave dipole.

PRC-25 sets operating on 50 Mc were used. Variable attenuators were used at the set input; these were adjusted to indicate an elevation improvement by means of keeping the set output quieting level constant. Vertical polarization was used.

Results are shown in Fig. 37. A well-known fact illustrated is the improvement resulting from higher antennas. Figure 38 shows a typical field measurement effort.

8. Subtask 8--Vertical-Incidence Ionospheric Measurements

Ionospheric observations are being conducted at the MRDC Laboratory at Bangkok. The C-2 vertical-incidence sounder, supplied and operated by USARPA, was modified near the end of the report period to more closely resemble the more recently developed C-4 sounder. During

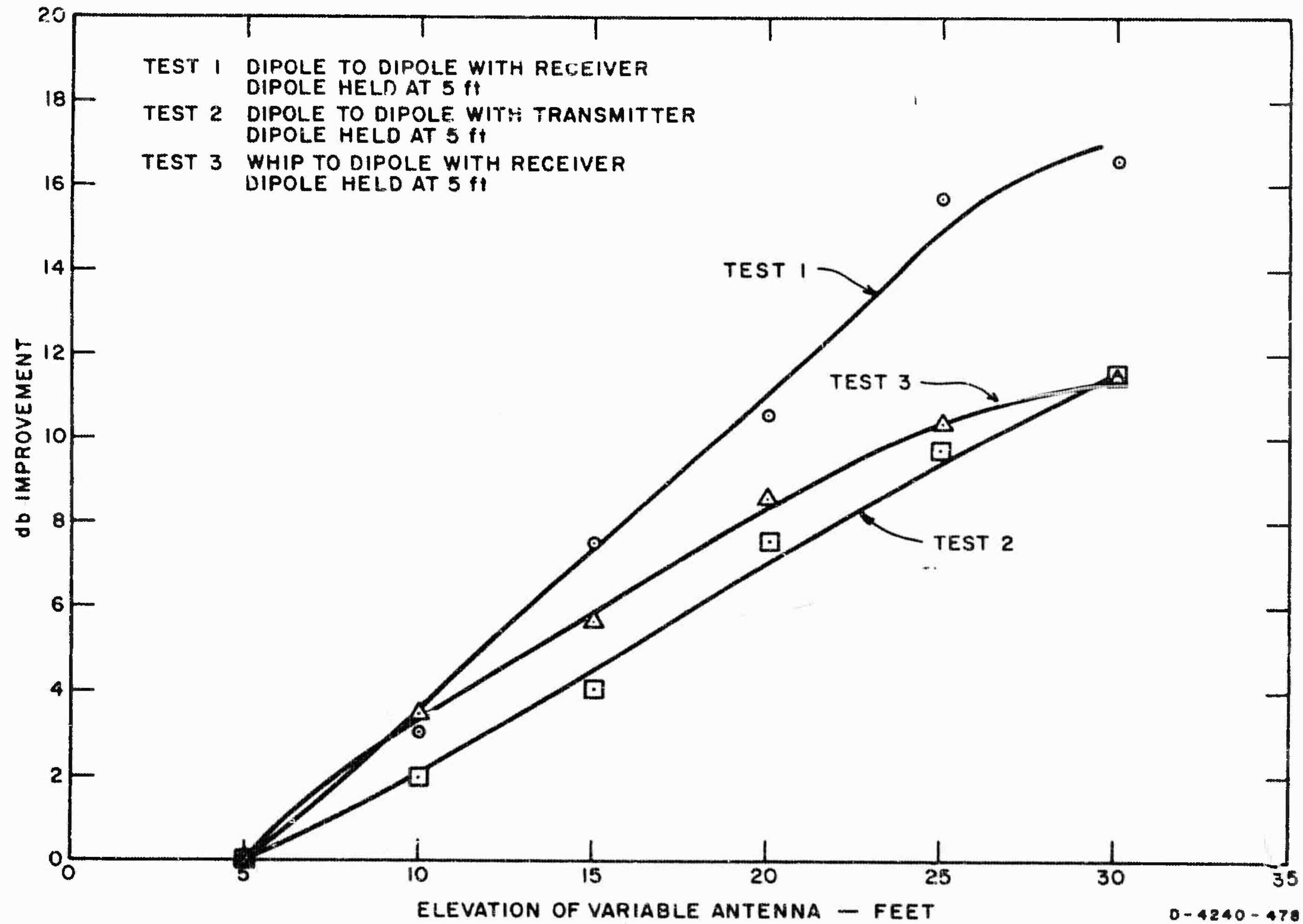

FIG. 37 ANTENNA ELEVATION EFFECTS

FIG. 38 AN/PRC-10 FIELD ANTENNA MEASUREMENTS

December 1964, Thai military personnel were assigned for training by RPA personnel in the operation and maintenance of the C-2 sounder unit. A number of Thai technicians are presently being trained.

Table III gives pertinent information about the site.

Table III

VERTICAL-INCIDENCE SOUNDER SITE
AT BANGKOK, THAILAND

Geographic		Geomagnetic	
Latitude	Longitude	Latitude	Longitude
13.73°N	100.57°E	2.5°N	169.83°E

Dip angle: 10°N

Distance from dip equator: 450 km

Equipment:

Instrument: Type C-2 (automatic)

PRF: 60 pps

Frequency sweep time: 30 sec

Frequency sweep range: 1 to 25 Mc

Pulse duration: 50 μsec

Peak pulse power: approximately 10 kw.

The laboratory is now compiling and issuing monthly bulletins of Ionospheric Data (Sec. III), based upon the C-2 measurements and their analysis.

A typical bulletin contains Table III information, a section on terminology and symbols, ionospheric data, and summary graphs.

A typical data sheet and a median value page are given in Tables IV and V, respectively; a summary graph is shown in Fig. 39. Exterior and interior views of the C-2 sounder are shown in Figs. 40 and 41, respectively.

Characteristic: foF2

Table IV

IONOSPHERIC DATA

Sweep: 1 Mc to 25 Mc in 0.5 minut

June 1964

Observed at:
Bangkok, Thailand
Lat. 13.73° N, Long. 100.57° E
105° E Mean Time (GMT + 7 hours)

Date \ Hour	00	01	02	03	04	05	06	07	08	09	10	11	12	1
1	F	U021F	A	A	B	A	C	045*	053	065	063	064	052	0
2	F	F	F	F	F	A	U033S	048	053	060	067	061	054	0
3	018	F	A	A	A	A	036	053	062	068	065	065	062	0
4	022	F	U021F	F	A	A	038	063	064	A	A	A	A	
5	U022F	F	F	B	U022F	F	036	055	065	064	061	052	055	
6	024	U023F	U025F	F	F	B	033	U049S	062	056	056	055	063	0
7	U026F	026	U023F	A	A	B	U039S	062	070	064	065	U052S	U059S	0
8	A	F	A	A	A	A	040	058	068	065	D052R	D050R	062	0
9	F	U021F	A	A	A	A	038	055	054	052	052	055	062	C
10	A	A	A	A	A	A	037	055	056	058	U050S	A	A	C
11	027	025	U025F	020	019	015	043	064	078	U037S	065	065	065	C
12	026	A	A	A	A	A	034	052	063	068	063	060	058	C
13	F	F	F	F	F	U023F	U03[illegible]S	U047S	056	U056S	C	053	057	C
14	F	F	F	F	F	A	U039S	U047S	U055S	057	A	A	A	C
15	U022S	F	F	F	F	A	038	U047S	U060S	057	053	D045R	D047R	DC
16	B	B	B	F	F	A	036	058	055	U055S	D053R	D047S	052	C
17	U024S	F	B	B	B	B	036	055	060	067	068	067	067	C
18	044	U033F	U021F	F	U019F	016	035	U047S	061	063	C	C	C	
19	A	A	A	A	A	A	036	058	065	C	C	C	065	C
20	024	U025F	A	B	F	A	036	055	U076S	077	082	072	076	C
21	U032F	B	B	B	021	022	045	055	060	064	070	072	C	
22	031	026	023	021	023	B	039	055	057	060	058	060	062	
23	038	031	029	025	028	024	044	051	061	068	071	068	063	
24	U029F	U026F	B	B	A	A	035	057	066	070	065	051	054	
25	029	F	022	B	B	A	U038S	055	057	061	056	051	060	
26	034	F	F	A	B	A	036	062	055	068	057	055	066	
27	027	F	A	A	A	A	042	049	063	070	U068S	052	058	U
28	F	F	F	F	F	F	U055S	U054S	058	068	067	065	067	U
29	C	C	C	C	C	C	C	C	C	C	C	C	C	
30	C	C	C	C	C	C	C	C	C	C	C	C	C	
31														
Median	027	026	023	021	022	022	037	055	061	064	063	055	062	
Count	18	10	8	3	6	5	27	28	28	26	23	20	22	
UQ	031	026	025	023	023	024	039	058	065	068	067	065	065	
LQ	024	023	023	021	019	016	036	049	056	058	056	053	057	
QR	7	3	2	2	4	8	3	9	9	10	11	12	8	

*Tabulation of 045 = 4.5 Mc.

Table IV

IONOSPHERIC DATA

Sweep: 1 Mc to 25 Mc in 0.5 minute

June 1964

	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	065	063	054	052	057	053	063	073	083	077	070	073	U063S	053	046
	060	067	061	054	067	068	076	078	085	086	101	U039S	U025S	B	B
	068	065	065	062	065	073	077	073	075	075	080	046	U034S	S	A
	A	A	A	A	A	073	077	067	077	071	079	058	U042S	A	022
	064	061	052	055	S	A	064	066	066	080	082	085	052	037	026
	056	056	055	063	064	063	063	070	075	085	080	U057S	U041S	U037S	031
	064	065	U052S	U059S	062	070	076	082	074	069	068	059	053	U037S	B
	065	D052R	D050R	062	065	064	071	070	068	075	076	059	046	038	U035F
	052	052	055	062	071	076	C	087	089	063	072	U039S	B	A	A
	058	U050S	A	A	054	A	085	096	072	070	070	069	064	047	035
	U037S	065	065	065	070	075	083	086	086	090	084	068	038	030	A
	068	063	060	058	070	071	081	C	C	C	085	070	U048F	U036S	U032S
	U056S	C	053	057	066	075	079	085	U095S	087	070	U067S	U060S	U050S	F
S	057	A	A	A	059	067	074	073	077	U080S	085	U080S	037	B	B
S	057	053	D045R	D047R	D047R	D047S	056	U066S	074	082	085	061	036	B	B
	U055S	D053R	D047S	052	054	055	060	066	073	071	080	087	U046S	U030S	023
	067	068	067	067	065	U071S	075	075	082	077	071	061	057	052	041
	063	C	C	C	C	C	C	C	C	C	C	061	043	037	F
	C	C	C	065	068	C	C	C	C	080	085	057	046	032	025
S	077	082	072	076	082	085	085	087	082	085	085	073	058	050	041
	064	070	072	C	C	C	C	070	077	082	084	072	054	U050S	039
	060	058	060	062	065	A	071	077	078	080	080	068	060	U047S	043
	068	071	068	063	065	074	084	075	075	078	082	066	A	B	A
	070	065	051	054	060	065	070	075	U072S	078	U080S	U075S	U048S	036	A
	061	056	051	060	065	068	073	075	U072S	U010S	U082S	S	U035S	036	035
	068	057	055	066	064	074	U070S	U074S	084	091	U085S	U040S	A	U021S	023
	070	U068S	052	058	U054S	070	072	075	075	084	084	068	062	045	U045F
	068	067	065	067	U075S	082	080	082	C	C	C	C	C	C	C
	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
	064	063	055	062	065	071	075	075	076	080	081	067	048	037	035
	26	23	20	22	23	21	24	25	24	25	26	26	24	20	16
	068	067	065	065	068	075	080	082	083	085	085	072	058	047	041
	058	056	053	057	059	066	070	070	074	075	076	058	039	036	026
	10	11	12	8	9	9	10	12	9	10	9	17	19	11	15

2

Table V

MEDIAN VALUES JUNE 1964

Hour Local	fmin (Mc)	foF_2 (Mc)	$M(3000)F_2$ (Mc)	F (km)	$h'F_2$ (km)	h'F (Mc)	$M(3000)F_1$ (Mc)	fbE_s (Mc)	foE_s (Mc)	$h'E_s$ (km)
00	1.8	2.7	3.05	-	300	-	-	2.2	3.8	103
01	1.5	2.6	3.25	-	280	-	-	1.6	2.6	103
02	1.4	2.3	3.25	-	290	-	-	1.7	4.4	103
03	1.3	2.1	3.30	-	300	-	-	1.6	3.6	110
04	1.2	2.2	3.30	-	230	-	-	1.8	2.7	100
05	1.5	2.2	3.60	-	260	-	-	-	3.3	100
06	2.0	3.7	3.30	-	250	-	-	2.5	2.9	107
07	2.4	5.5	3.10	-	220	-	-	3.0	4.1	100
08	2.5	6.1	2.90	315	200	-	-	3.3	4.5	100
09	2.9	6.4	2.60	400	200	4.2	4.10	3.5	4.8	100
10	3.0	6.3	2.50	430	190	4.2	4.20	3.8	4.9	100
11	3.3	5.5	2.60	450	185	4.3	4.20	3.9	5.1	100
12	3.4	6.2	2.50	450	195	4.4	4.20	4.1	5.5	100
13	3.4	6.5	2.50	415	180	4.3	4.20	3.9	5.3	100
14	3.1	7.1	2.60	390	190	4.3	4.10	3.7	5.0	100
15	3.0	7.5	2.70	360	200	4.1	4.10	3.7	5.0	100
16	2.5	7.5	2.85	340	210	4.0	3.95	3.4	4.0	100
17	2.5	7.6	2.95	-	240	-	-	3.4	3.7	97
18	2.1	8.0	3.10	-	240	-	-	2.8	4.5	98
19	2.0	8.1	3.30	-	233	-	-	3.0	3.7	90
20	2.0	6.7	3.45	-	215	-	-	2.6	3.3	95
21	2.0	4.8	3.40	-	218	-	-	2.6	2.9	90
22	2.0	3.7	3.38	-	250	-	-	2.5	3.1	100
23	1.8	3.5	3.20	-	290	-	-	-	3.3	103

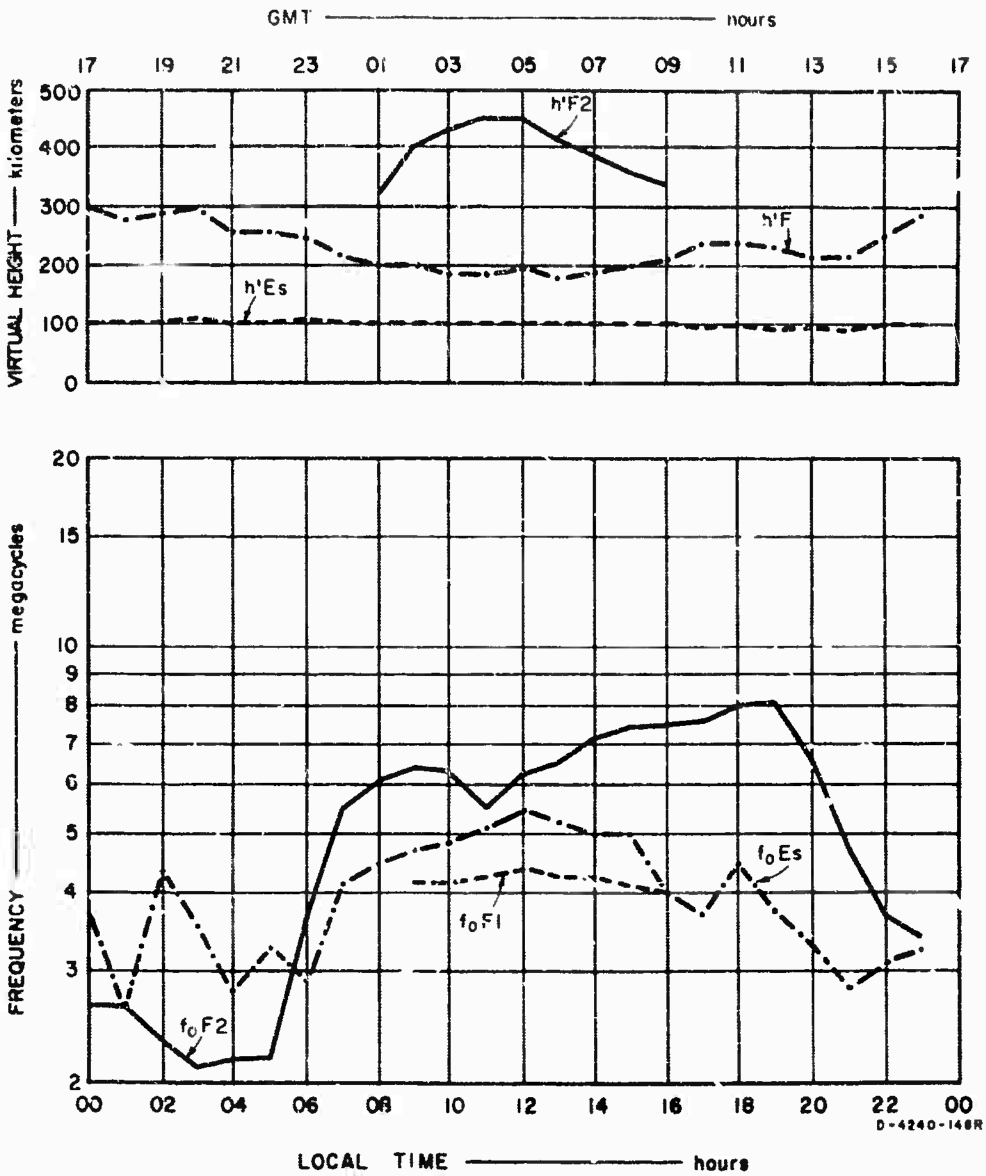

FIG. 39 IONOSPHERIC DATA, MONTHLY MEDIAN CHARACTERISTICS, BANGKOK, JUNE 1964

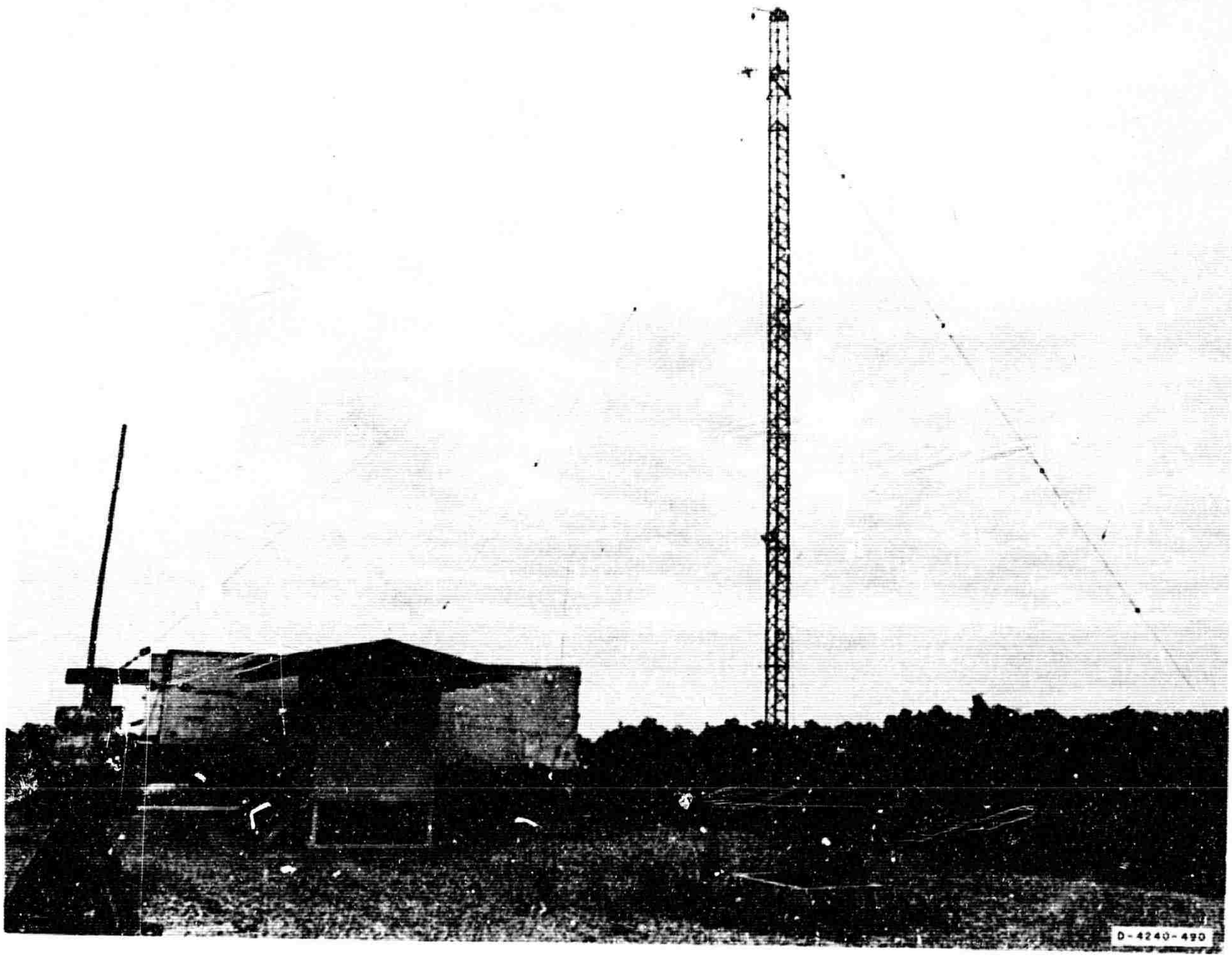

FIG. 40 C-2 SOUNDER, EXTERIOR VIEW

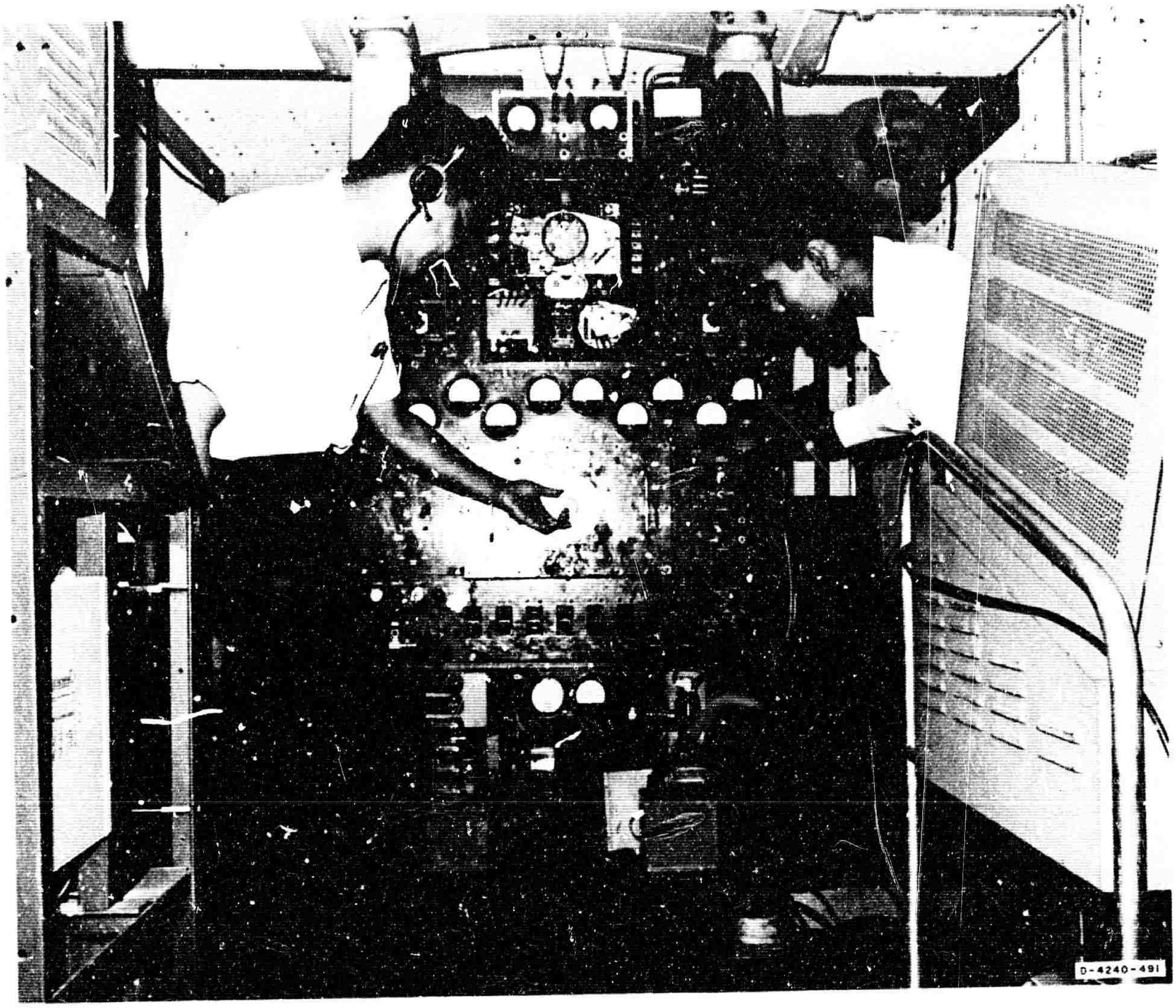

FIG. 41 C-2 SOUNDER, INTERIOR VIEW

9. General Support

Efforts which do not fit under the eight subtasks are classified as support to MRDC. These efforts are further classified as direct requests from the Thai MOD or ARPA-RDFU, or as necessary routine laboratory efforts.

Examples of the first type are:

(1) Village Radio Program study
(2) Thermo-electric generator
(3) Low MUF study
(4) Vietnam patrol antenna study
(5) Thai military radio-teletype experiments
(6) Ionospheric deviative absorption experiment.

a. Thai Military Radio-Teletype Experiments

Thai military personnel with support from Institute laboratory personnel have conducted a series of experiments using U.S. AN/GRC-26 radio-teletype equipment. This equipment was first modified by the Royal Thai Army to incorporate Thai language teletypewriters (Nippon Electric Company), thus providing a Thai language capability in such vans.

Following this modification, tests were performed at the laboratory to improve remote control characteristics, and satisfactory remote control at a mile or more was achieved. Field tests of the same system were conducted between Bangkok and Korat.

The next phase of effort was to use the same system to test ideas on diversity applications which resulted from the dipole orientation theories and experiments (Subtask 3). These results are discussed in this report under Subtask 3.

In the last phase of this effort, the Royal Thai Army personnel, with MRDC Electronics Laboratory support, has initiated an investigation using the Thai language teletypewriters over a U.S. military-type VHF carrier system.

b. Thermo-Electric Generator

Some laboratory effort was devoted to a study of a charcoal-fired thermo-electric generator. The thought was that such a generator (already developed by Minnesota Mining and Manufacturing Company) could be used in remote Thai villages to power TR-20 village radio equipment.

In the tests, the generator worked satisfactorily. However, due to the heavy current required in the TR-20 transmit mode, the battery associated with the generator was found to be inadequate (internal resistance too high). Calculations were then made to estimate the generator capability to permit a reasonable transmit-to-receive ratio on the TR-20, assuming a sufficiently large storage battery were used. The calculations showed that the thermo-electric generator could produce 150 watt-hours per 12-hour day; with this charging cycle, the transmitter could operate only 27 minutes per 8-hour day.

Thus, improved performance requires more generators or a larger generator. An alternate solution to the problem of obtaining operating times greater than about one-half hour per day, using the thermo-electric generator tested, would involve a radio set with a reduced transmit current requirement.

c. TR-20 Village Radio Study

During this period, laboratory personnel participated in a study of technical problems associated with the Thailand Village Radio Program. Model TR-20 transceivers are used in this system. These units are normally used for communication between a Tombon (subdistrict administrative center) and an Amphur (district center), and are usually quite dependable. Communication failures include power supply failure or set malfunction.

The TR-20 transceiver is an amplitude-modulated (voice), one-channel, crystal-controlled unit operating in the 30-40-Mc range, with a power of 20 watts. The unit can be powered from a 12-volt dc source or a 115-volt ac source; it is simple to operate and requires no adjustment or tuning after initial installation. At all sites visited, the A-20 antenna was used; this is a standard monopole with a three-wire counterpoise, at least 25 feet above ground.

Power supply failure results from lack of spare batteries (no village has commercial power) or charging facilities. Battery life is a direct function of transmitting time because the receiver (all-transistorized) drain is quite low. Transportation of the batteries to the Amphur for recharging may take several days during the dry season and may be impossible during the rainy season. The usual supply consists of two 6-volt, 70-ampere-hour batteries in series.

The maximum effective range of the TR-20 with the present antennas is estimated at about 50 km over flat land with only scattered trees. A greater range would be desirable to allow the Changwad (provincial capitol) to communicate with its Amphurs directly without the necessity of relaying. This could be accomplished by using a directional antenna and/or elevating the antenna. The latter would be especially beneficial in heavily-forested areas where elevation above the forest canopy would greatly improve the range.

No repair facilities or back-up sets are locally available. When failure does occur, the set must be shipped to Bangkok for repair and the Tombon is left without communications for two to four months.

These and other aspects of the set and system are under study, such as useful range and reliability.

d. Routine Laboratory Effort

Some routine but important Bangkok laboratory efforts are: operation of a VLF receiver to maintain accurate calibration of the laboratory time and frequency standard based upon received 16-kc signals from station GBR, Rugby, England; operation of other T-van equipment, such as the lightning flash counter, satellite recording system, and six-channel noise recorder; repair and calibration of laboratory test equipment; and communication between the T-van and field crews via HF SSB equipment.

Other laboratory activities are conducting seminars and classes for training Thai technicians and NCO's in equipment repair and calibration, and making scientific contacts in Thailand and elsewhere in Southeast Asia.

e. Scientific Contacts

An important part of the laboratory activities has been the numerous scientific contacts established with ionospheric research groups in other Southeast Asian countries. Such trips permit the exchange of information with other communication and/or research facilities concerning ionosondes, lightning flash counters, noise measurements, ionospheric research, and satellite data analysis.

This exchange brings laboratory personnel up to date on items of communication research pertinent to this area, enlarges the perspective of laboratory guidance, and provides needed scientific information.

Visits have been made to ionospheric research groups in Singapore, India, Japan, Hong Kong, Macao, Malaysia, and the U.S. Ionospheric data are exchanged between Bangkok and Japan, Macao Taiwan, Hong Kong, the Philippines, Singapore, and India. A joint satellite reception and data analysis effort is conducted by Bangkok, Singapore, and Hong Kong. Other joint experiments with other countries are under consideration.

Local contacts are maintained with the Thai Meteorological Department, Chulalongkorn University, Postal Telephone and Telegraph Organization, National Documentation Center, Applied Scientific Research Corporation, and many other Thai organizations.

f. Seminars

During this period, a number of seminars on pertinent technical topics were conducted, as follows:

(1) Discussion of bandwidth concepts--R. L. Brown

(2) Solar flares, sudden ionospheric disturbances, and their radio effects--E. T. Pierce, G. H. Hagn

(3) Absorption considerations in ionospheric path system calculations--G. H. Hagn

(4) Signals above the MUF--G. H. Hagn

(5) ARN-3--R. L. Brown

(6) Effective range of lightning flash counter--E. T. Pierce

(7) Fading of radio waves--K. D. Felperin

(8) Effective range of VHF man-pack radios in forests--G. H. Hagn.

g. <u>Implementation Plans</u>

Implementation plans have been written as follows (using new task numbers):

Task 1--Conduct of RF Noise Measurements

Task 2--Special Magnetic and Ionospheric Investigations

Task 3--Investigation of Ionospheric Factors Related to Local Frequency Prediction

Task 4--Investigation of Effects of Tropical Environment on Antenna Performance.

These plans were originally submitted by R. E. Leo on about 20 October 1964 and have undergone subsequent revisions and refinements.

h. <u>Miscellaneous</u>

Laboratory personnel have devoted some time to the Academic Research Committee. This committee, formed by ARPA-RDFU, has been established to promote a closer match between MRDC research needs and Thai University research capabilities, in order to accomplish more in-country military research. After a series of meetings and discussions, a charter draft was submitted to MOD and ARPA-RDFU in January 1965.

III PUBLICATIONS

The following reports have been published on the contract. Those marked with an asterisk were published during the period covered by this report.

W. R. Vincent, "Research-Engineering and Support for Tropical Communications," Semiannual Report 1 (March 1963).

"Research-Engineering and Support for Tropical Communications," Semiannual Report 2 (September 1963).

* "Research-Engineering and Support for Tropical Communications," Semiannual Report 3 (October 1964).

* "Research-Engineering and Support for Tropical Communications," Final Report, Vol. 1 (September 1964).

W. R. Vincent, "Voice Tests on Man-Pack Radios in a Tropical Environment," Research Memorandum 2 (July 1963).

W. R. Vincent, "Field Tests on Man-Pack Radios in a Tropical Environment," Research Memorandum 3 (July 1963).

T. S. Cory, "Scale-Model Measurements on a Sloping-Wire Antenna," Research Memorandum 4 (June 1963).

G. H. Hagn, "Orientation of Linearly Polarized HF Antennas for Short-Path Communication Via the Ionosphere near the Geomagnetic Equator," Research Memorandum 5 (August 1963).

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T. S. Cory and W. A. Ray, "Measured Impedances of some Tactical Antennas near Ground," Research Memorandum 7 (February 1964).

* G. H. Hagn, "Absorption of Ionospherically Propagated HF Radio Waves under Conditions where the Quasi-Transverse (QT) Approximation is Valid," Special Technical Report 9 (September 1964).

* V. T. Nimit, "Ionospheric Data: Bangkok, Thailand," Ionospheric Data Report--September 1963 (March 1965).

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* V. T. Nimit, "Ionospheric Data: Bangkok, Thailand," Ionospheric Data Report--October 1964 (March 1965).

* V. T. Nimit, "Ionospheric Data: Bangkok, Thailand," Ionospheric Data Report--November 1964 (March 1965).

* V. T. Nimit, "Ionospheric Data: Bangkok, Thailand," Ionospheric Data Report--December 1964 (March 1965).

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1. "Tropical Propagation Research," Semiannual Report Number 4, Contract DA-36-039 SC-90889, Jansky & Bailey, a division of Atlantic Research Corporation, Alexandria, Virginia (January-June 1964).
2. "Groundwave Field Intensities Including Groundwave Field Intensities within the Line of Sight," Technical Report 3, Signal Corp Radio Propagation Agency, Fort Monmouth, New Jersey (Revised June 1949, Second Printing April 1956).
3. H. Bremmer, Terrestrial Radio Waves, Elsevier Publishing Company, Amsterdam, New York (1949).
4. O. K. Garriott, "The Determination of Ionospheric Electron Content and Distribution from Satellite Observations," J. Geophys. Res., 65, No. 4.
5. E. A. Clarke and E. M. Young, "The HF Propagation Prediction Programs for the IBM 7090 Computer," Final Technical Report 2, Contract DA-36-039-SC-85052, SRI Project 3340, Stanford Research Institute, Menlo Park, California (May 1962).
6. B. W. Osborne, "Note on Ionospheric Conditions which may Affect Tropical Broadcasting Services after Sunset," J. British Institute Radio Engineers 12, 110 (February 1952).
7. T. W. Bennington, "Equatorial Ionospheric Effects: Post-Sunset Fading on Long-Distance Radio Circuits," Wireless World 66, pp. 501-506 (1960).
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9. C. Barnes, "Xeledop Antenna Pattern Measuring Equipment, 2 to 50 Mc," Stanford Research Institute, Menlo Park, California (January 1965).

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11. SUPPLEMENTARY NOTES Report on communications research in tropical vegetated environments.	12. SPONSORING MILITARY ACTIVITY U. S. Army Electronics Command Fort Monmouth, N.J.

13. ABSTRACT

Communications research in a tropical environment is needed to develop improved equipment and techniques for use by military forces in Southeast Asia and other areas of similar environment. This report covers the following research effort in Thailand during 1 September 1964 through 31 March 1965:

1. Test and evaluation of tactical communication techniques and devices was performed.
2. RF noise measurement study was continued.
3. A series of HF antenna orientation measurements were conducted.
4. Faraday rotation experiments were continued using data from satellites Transit 4A and Beacon S66.
5. Ionospheric data from a C-2 sounder in Bangkok, Thailand has continued to be compiled and published in report form.
6. Xeledop antenna pattern measurements of selected field antennas were made over flat terrain and in selected forest areas in CONUS.

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Techniques	10	4				
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SEA - Southeast Asia		4				
Thailand - SEA				4		
RF Noise			8,7	4		
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